# REPORT RESUMES

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HELPING CHILDREN LEARN SCIENCE, A SELECTION OF ARTICLES REPRINTED FROM SCIENCE AND CHILDREN.

BY- HOPMAN, ANNE B.

NATIONAL SCIENCE TEACHERS ASSN., WASHINGTON, D.C.

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INCLUDED ARE SELECTED ARTICLES FROM "SCIENCE AND CHILDREN" COVERING THE PERIOD SEPTEMBER 1963 THROUGH MAY 1966. THE SELECTION CRITERIA WERE THAT THE ARTICLES (1) PRESENT MATERIAL WHICH IS CONSISTENT WITH ACCEPTED PHILOSOPHY AND PRACTICES AND WITH THE LATEST TRENDS IN SCIENCE EDUCATION, AND (2) PROVIDE USABLE MATERIAL FOR CLASSROOM TEACHERS, CURRICULUM PERSONNEL, AND ADMINISTRATORS WHO ARE NOT SPECIALISTS. THE SELECTED ARTICLES ARE PRESENTED IN FIVE CATEGORIES--(1) OBJECTIVES FOR TEACHING SCIENCE, (2) BACKGROUND INFORMATION FOR THE TEACHER OF SCIENCE, (3) RESOURCES FOR TEACHING-LEARNING, (4) CLASSROOM TEACHING-LEARNING EXPERIENCES, AND (5) EXPERIMENTAL SCIENCE CURRICULUM STUDIES. (DS)

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# HELPING CHILDREN LEARN SCIENCE

A Selection of Articles
Reprinted from

## SCIENCE and Children

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SE004 232

# A word about SCIENCE and Children

The articles in this book are drawn from a fresh and unique source—a periodical devoted to the thousands of teachers in the elementary schools who recognize the importance of being knowledgeable about the role of science in the living and learning of millions of children. Although most of these elementary teachers are not science specialists, they may, in fact, know a great deal about science and be constantly "exploring" in science in their everyday environment. They are interested in seeking more effective ways of organizing knowledge and experience into curricula and classroom activities. It is important that they do this with eagerness, enjoyment, and yet with confidence in the durability and usefulness of the processes and basic conceptions of science.

The National Science Teachers Association has traditionally played a facilitating role in this venture—with the Elementary School Science Bulletin, published from May 1952 through June 1963; with special studies, publications, and the activities of its curriculum committee; and finally with *Science and Children,* a periodical launched in September 1963.

The aims of *Science and Children* are to:

- Give practical help to the classroom teacher in the teaching of science
- Offer suggestions to administrators and curriculum personnel for science curriculum planning and the implementation of an effective science program
- Provide information and inspiration in relation to the structure, spirit, and function of science
- Communicate views of trends in science education

*Science and Children* is published monthly, September through December and February through May. It is included with elementary, comprehensive, and life memberships in the National Science Teachers Association and is also available to other individuals, schools, and libraries on a subscription basis.

NSTA Elementary Membership, $4 per year
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# HELPING CHILDREN LEARN SCIENCE

A Selection of Articles
Reprinted from

SCIENCE and Children

compiled by Anne B. Hopman

NATIONAL SCIENCE TEACHERS ASSOCIATION 1966

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# PREFACE

The compilers of this collection of articles from *Science and Children* have had the pleasant task of beginning a mosaic of science teaching ideas for the elementary schools. The pieces at hand have been strong, rich, and colorful; the design is well started. We are glad to present this publication as a record of the pattern already begun. We hope that teachers and administrators in the elementary schools will build upon this beginning with current and future materials from *Science and Children*.

In the preparation of this publication, all the contents of the magazine from September 1963 through May 1966 were carefully reviewed by a group of elementary-school educators.*

We had two criteria in mind: Articles that

1. Present material which is consistent with accepted philosophy and practices and with the latest trends in science education
2. Provide usable material for classroom teachers, curriculum personnel, and administrators who are not science specialists

The selected articles are presented in five categories: objectives for teaching science, background information for the teacher of science, resources for teaching-learning, classroom teaching-learning experiences, and experimental science curriculum studies.

We recommend the book to the classroom teacher in the belief that it can

- Open doors to possibilities for teaching science
- Offer some strategies for planning, carrying out, and evaluating the science curriculum
- Suggest improvements in skill in science teaching
- Be a reference source of science content
- Suggest teaching-learning experiences
- Offer ideas for the use of resources
- Introduce and review some of the experimental curriculum studies

For other curriculum personnel and administrators, we hope that this book can

- Illuminate the objectives of science teaching
- Make suggestions for curriculum planning
- Help in the recognition of good science teaching
- Assist in evaluating present programs
- Provide a check of the use of resources
- Serve as a reference source for a science curriculum committee

The other members of the committee who helped to select the material were Mr. William J. Preston, Assistant Superintendent for Curriculum and Instruction; Mrs. Patricia Olson, Primary Teacher, R. B. Miller School; and Mrs. Sharon Wagenblast, Intermediate Teacher, R. B. Miller School, who are also with the Hammond, Indiana Public Schools. We are grateful to Standing Committee II (Publications Committee) of the National Science Teachers Association and to its chairman, Katherine E. Hill, for suggesting this publication and for their encouragement during its preparation. We have enjoyed the assignment.

To our readers, we would say only: We hope you will be inspired and helped by our efforts and that you will continue to fill in this mosaic of science teaching in the elementary schools.

ANNE B. HOPMAN
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* The author's affiliation shown is that at the time of original publication.

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# SECTION 1 STRATEGIES FOR SCIENCE IN THE ELEMENTARY SCHOOL

## Introduction

The development of an effective science curriculum in the elementary school starts with a well-defined strategy. The first step in planning is the identification of objectives for the teaching of science. Therefore, the "whys" for teaching science must be determined to provide a framework for the organization of a program, the selection of learning experiences, the use of resources, the type of teacher guidance, and ways of evaluating the efficacy of a program.

This section presents basic ideas to be considered in planning a program of science for elementary-school children. The first article explores purposes of teaching science based upon a commitment to children. The next few articles present views of the nature of science and the relationship of what science is to objectives and to teaching procedures. Essential to the development of a learning program of science for children is consideration of the processes of thinking. Therefore, a few articles follow which deal with how children learn and the development of concepts. Other articles look at science education from the point of view of teaching very young children and those who are culturally disadvantaged. The last three articles discuss recent trends in the improvement of science instruction, the role of a teacher in adapting curriculum to specific teaching situations, and the importance of a continuous kindergarten through grade 12 program of science.

Each elementary educator is in a strategic position to do something about the development of a master plan for the teaching of science in the elementary school. The classroom teacher is the key person in translating a strategy into meaningful science experiences for all children in the elementary school.

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# SCIENCE for CHILDREN —WHY?

**KATHERINE E. HILL**
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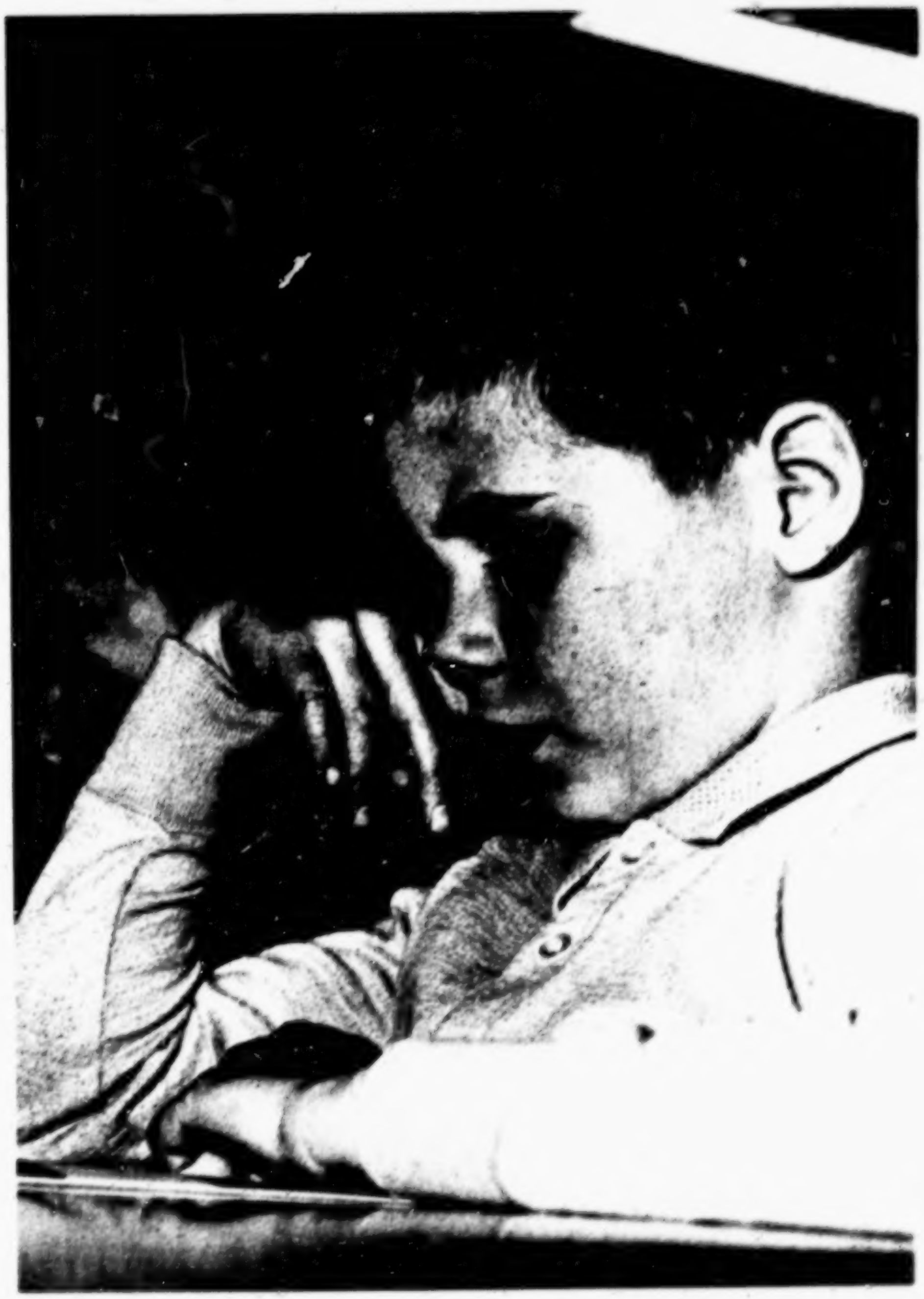

ASSISTING children to learn is both a privilege and a challenge. The privilege is in watching a child's expression of bafflement change to one of comprehension, in finding a child so involved in reading or observing or some other endeavor that it is difficult to gain his attention, in hearing a child enthusiastically sharing a new idea with his friend. The challenge comes in grappling with the problems of how to assist children in their learning and of what the content of the learning shall be.

Research in the teaching of science in the elementary schools has provided considerable information, much of it in terms of what children are capable of learning. We know, for example, that boys and girls can learn to observe, to classify, to measure, to inquire, to infer, to hypothesize. Further, we know that they can begin to acquire each of these skills at an early age and can improve in their understanding and use of the skills as they grow older.

Designing and field-testing units focused on building concepts related to such topics as microscopic organisms, cells, worms, stars, systems, plant germination, action and reaction, magnetism, and motion has provided additional information. We know that children can learn countless concepts about natural phenomena.

In short, recent research makes it clear that children are capable of learning a great deal. Knowing *how* to assist children in their learning is perhaps even more useful. But such knowledge does not solve the problem of *what* children shall learn.

Perhaps the answer to what shall be taught in science lies in a consideration of the question, "Science for children—why?" Some educators stress that the reason boys and girls should learn skills and concepts of science is to give them insights into how scientists work, perhaps even to produce "little scientists."

Does such an attitude bring education at the elementary school level dangerously close to pushing children toward a vocational choice before they are twelve years of age? Is it a defensible goal to lead children to understand how scientists work any more than how physicians, artists, teachers, musicians, bakers, carpenters, steam shovel operators, secretaries, authors, generals, politicians, or hundreds of other people work?

The purpose of learning in the elementary schools is not that of learning how to perform as a scientist or as a worker in any other area. Rather, the purpose is to assist boys and girls to build skills and concepts which will enable them to cope more effectively this year, this month, this day of their lives with the objects, forces, and events which comprise their environment. The science skills—observation, measurement, classification, inference, and so on—can be translated into immediate behavior by the child as he attempts to understand the phenomena of science encountered in his environment.

However, boys and girls must also realize that these skills under consideration are not the exclusive property of science. Observation is used by the child who paints his impressions of a landscape. Inferences are drawn by the child who considers the work people do and the rewards of their work. Surely, if many of the skills needed in science are needed in other curriculum areas, it is not wise to center a science curriculum on the development of skills.

Skills must be built as one uses the subject matter of a discipline. A child's ability to classify is developed as he considers land forms, as shown on maps being used in social studies, uses crayons or paint in art, and studies the structure of animals in science.

The curriculum worker is faced, then, with the problem of deciding which science concepts shall be developed. Having elementary school children take courses in botany, chemistry, or any of the other science disciplines was discarded long ago. So was the idea of developing concepts related to topics chosen solely on some such opportunistic basis as children's interest or prominence in the news.

More and more, children are being considered as growing, developing individuals who are challenged by meeting closely related science phenomena day after day. For this reason, a defensible method for selecting content for the science curriculum is: (1) to determine the basic ideas, patterns, themes, or conceptual schemes which are useful in interpreting natural phenomena and (2) to select those concepts which give promise of building optimum understandings of the basic ideas which can be employed throughout a lifetime.

There is no final agreement among educators, at this point, as to which are the basic patterns or conceptual schemes most useful in this respect. However, it is interesting to note the similarities in the patterns suggested from several sources.

Gerald S. Craig[1] suggests the following large patterns as guidelines for teaching and learning: (1) The Universe Is Very Large—Space, (2) The Earth Is Very Old—Time, (3) The Universe Is Constantly Changing—Change, (4) Life Is Adapted to the Environment—Adaptation, (5) There Are Great Variations in the Universe—Variety, (6) The Interdependence of Living Things—Interrelationships, and (7) The Interaction of Forces—Equilibrium and Balance.

Paul Brandwein[2] suggests these conceptual schemes as basic ideas: (1) Under ordinary conditions, matter can be changed but not annihilated or created; (2) Under ordinary conditions, energy can be changed or exchanged but not annihilated; (3) There is an interchange of materials and energy between living things and their environment; (4) The organism is a product of its heredity and environment; (5) The universe, and its component bodies are constantly changing; and (6) Living things have changed over the years.

In abbreviated form, the conceptual schemes proposed in the National Science Teachers Association publication, *Theory Into Action*,[3] are as follows: (1) All matter is composed of units called fundamental particles; under certain conditions these particles can be transformed into energy and vice versa; (2) Matter exists in the form of units which can be classified into hierarchies of organizational levels; (3) The behavior of matter in the universe can be described on a statistical basis; (4) Units of matter interact; (5) All units of matter tend toward equilibrium states. In the process of attaining equilibrium, energy transformations or matter transformations or matter-energy transformations occur; (6) One of the forms of energy is the motion of units of matter; (7) All matter exists in time and space and, since interactions occur among its units, matter is subject in some degree to changes with time.

A consideration of these basic patterns and conceptual schemes shows us, at once, that sufficient experiences must be provided each year to allow children to interact in depth with phenomena representative of the several aspects of natural environment. Such experiences might be thought of as those related to: (1) living things; (2) matter, energy, and motion; (3) Earth; and (4) Earth in space. Planning for such a variety of experiences annually is essential if all the patterns or conceptual schemes are to be conceived as operating throughout the natural environment.

Science for children—why? The answer lies in the hands of those responsible for developing curriculum in our elementary schools. Their commitment must be in terms of children, not in terms of science. They know that boys and girls need assistance in the continuous process of building those abilities needed in interpreting natural phenomena in the environment. If this is the answer to *why* science in the elementary school, then this is also the criterion to be employed in determining *what* skills and concepts of science shall be taught.

---

[1] Gerald S. Craig. *Science for the Elementary-School Teacher.* Ginn and Company, Boston, Massachusetts. 1964. p. 93-101.

[2] Paul F. Brandwein. *The Teaching of Science: Elements in a Strategy for Teaching Science in the Elementary School.* Harvard University Press, Cambridge, Massachusetts. 1962. p. 132-136.

[3] Paul DeHart Hurd, NSTA Curriculum Committee and the Conference on Science Concepts. *Theory Into Action.* National Science Teachers Association, Washington, D. C. 1964. p. 20.

# Science Teaching in the Elementary School

**PAUL E. BLACKWOOD**

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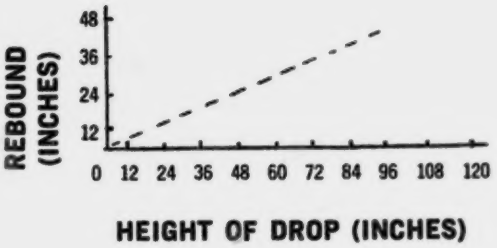
What you see and hear in the corridor of an elementary school is often related to what goes on in classrooms. This visitor was lured into a fifth-grade classroom by a girl energetically bouncing a red rubber ball.

Inside the classroom other pupils were dropping rubber balls. They were investigating how high a ball would bounce when dropped freely from various heights. After a short period of activity, the children and teacher were confronted with 15 sets of data collected independently by 15 two-man teams. What one team recorded is shown in Chart I.

**CHART I**

| Height of Drop (Inches) | TRIAL | REBOUND (Inches) |
|---|---|---|
| 24″ ( 2′) | 1 | 11.00″ |
| | 2 | 11.50″ |
| | 3 | 11.75″ |
| | Average | 11.41″ |
| 48″ ( 4′) | 1 | 22.50″ |
| | 2 | 22.75″ |
| | 3 | 23.25″ |
| | Average | 22.83″ |
| 72″ ( 6′) | 1 | 33.00″ |
| | 2 | 33.75″ |
| | 3 | 34.00″ |
| | Average | 33.58″ |
| 96″ ( 8′) | | ? |
| 120″ (10′) | | ? |

How would these results look on a graph? The question by the teacher was sufficient motivation to cause the team to prepare a graph of the results similar to the one below.



Additional questions began to emerge:

1. How far would the ball bounce if dropped from 8, 10, or 12 feet?
2. By using the graph, can one predict the height of rebound?
3. Is there a maximum height the ball will bounce, regardless of the distance it falls?
4. How does the bounce of different balls compare?
5. Do heavier balls bounce higher than lighter balls?

In another class, children were discussing the question, "How does the length of a stick's shadow change as the sun moves across the sky?" First, the children changed the question into a form which could be investigated more directly. They worded it this way: "What is the length of a stick's shadow at different times of the day?" An answer to this question could be obtained by direct measurement, and data collected to answer it would help answer the first question, so the class decided. It was not long before 15 pairs of pupils were busy in the schoolyard collecting information. Each pair was confronted with certain questions:

—How long a pole shall we use?

—Where shall we place it?

—At what intervals during the day shall we measure the shadow?

Two children decided to measure the length of the shadow of an 88-inch pole every hour from 8 a.m. to 3 p.m., just south of the school house. They measured it on June 7 and again on June 10 because the sun disappeared just after noon on the 7th. Their recorded data are illustrated in Chart II.

**CHART II**

**Length of Pole: 88″ (7′4″)**
**Position: South of School House**

| Time | Length | |
|---|---|---|
| | June 7 | June 10 |
| 8 a.m. | 122″ (10′2″) | |
| 9 a.m. | 81″ (6′9″) | |
| 10 a.m. | 54″ (4′6″) | |
| 11 a.m. | 37″ (3′1″) | |
| 12 m. | 28″ (2′4″) | |
| 1 p.m. | Cloudy | 36″ (3′) |
| 2 p.m. | Cloudy | 53″ (4′5″) |
| 3 p.m. | Cloudy | 79″ (6′7″) |

Based on these figures, the children were able to answer their questions about the changing length of shadows in relation to the position of the sun. But one youngster asked, "Does this experiment prove that the earth rotates or that the sun moves?"

The two learning experiences described above may well illustrate some characteristics of good science teaching. But a judgment can be made only in terms of what one accepts as a model of science education. Before evaluating these, or any science experiences, let us consider a model of science education which clearly recognizes two essential and perhaps interrelated features.

1. The nature of science, and
2. The purposes and methods of teaching science.

Surely a growing understanding of each of these by teachers of elementary school science is essential.

**1. The nature of science.**

A working definition of science is helpful in giving clues as to what may properly be included in the study of science. The following tentative definition has the virtue of including enough ingredients to reflect the breadth and richness of science. *Science is man's relentless search for verifiable patterns, concepts, descriptions, or explanations of phenomena in the universe.*

In this definition, we see that man is in the picture. Science is an enterprise, an activity of people. Science is people searching. It is men, women, and children investigating, inquiring, and seeking verifiable knowledge. It is relentless, a continuous, never-ending attempt to find more accurate descriptions of things and events and to seek reasonable explanations of these events. The search leads to new discoveries, to new insights about unifying patterns, to concepts, to understandings, and to new knowledge. Many of these observations, descriptions, and explanations have been recorded by scientists and are available for use by other people as they attempt to extend their knowledge and understanding of the natural environment. This recorded knowledge, about which people can communicate, is an important part of science.

A definition of science like that discussed above has been eschewed by some scientists on the grounds that you can define science better in terms of what scientists do. It seems simple to say, "Science is what scientists do." But to understand this statement requires an analysis of what it is that men and women do when they are being scientists. Let us then, in our exploration of what science is, look briefly at three of the basic things that scientists do.

*a. Scientists make descriptions.* What is in the universe? How many? How much? How long? How frequently? Where? When? Under what circumstances? Answers to such questions are descriptions.

Astronomers use telescopes, cameras, and instruments of other kinds. They use mathematics and their minds to try to get a picture of our universe and how the bodies in space are interrelated. Geologists study rock structures, formations of the earth, and changes in its surface. The study requires careful observation and accurate reporting. Physicists attempt to find out how energy flows from one material to another and what happens to the materials.

Thus, scientists attempt to describe what is, how things are, what things are like, how they change, and how they interrelate. Improved descriptions of things and events in our universe enable scientists to discover unity within vast diversity. Methods that have proven practical in discovering the elements of unity within diversity and in getting "check-up-able" knowledge we sometimes call scientific methods. As other people use these methods, they are able to verify what someone else has observed.

*b. Scientists make explanations.* In a sense, scientists attempt to tell "why" certain events and phenomena occur the way they do. This usually involves observing carefully how things interact with each other. What are the interrelationships? What precedes what? What follows what? Under what conditions do certain phenomena occur? Making explanations usually involves showing the connections between events or phenomena.

In a way, an explanation is a very careful description. For example, to explain why water evaporates from an open dish requires knowledge about the physical structure of water, about the nature of molecular action, about the capacity of air to hold water molecules, the behavior of water molecules when heat energy is increased, and the like. Scientists are detectives attempting to put descriptions together in ways that help us understand events. In this way, they make explanations.

*c. Scientists make predictions.* In order to make knowledge more widely applicable and to extend our confidence in its validity, it must be tested in many situations. Extending our knowledge to new situations involves prediction. We have observed that water will evaporate from a dish on a window sill. We predict that it will evaporate also if placed on a warm radiator. We test to see. If it does, then our prediction is correct.

Scientists are continually testing to see if principles that apply in one situation will apply in another. Making use of a concept of generalizations or law in a situation which has not yet been tested involves prediction. Scientists have not been on the moon. Yet numerous predictions of what it is like there have been made and may be proven true. Actually, the acceptance of certain predictions as fact enables planning for the moon launch to proceed with confidence. Making predictions is an important part of what scientists do.

In making descriptions, explanations, and predictions, scientists use their minds; they use ideas of their own and ideas of others as tools for testing and gaining knowledge. They use many resources to get valid answers to their questions or solutions to their problems. They may invent new tools with which to observe or to check phenomena more accurately. Thus, scientists do many things in relation to making valid descriptions, explanations, and predictions.

Now, having considered briefly the meaning of science and what scientists do, it is appropriate to ask whether good science teaching should make provisions for children to experience science in the sense discussed. Let us postpone consideration of this question while we examine the second feature of our science education model.

### 2. The purposes and methods of science teaching.

One way of representing a science education program is shown in the accompanying figures. It provides us with a way of describing a science education program and of questioning and constructively criticizing our efforts. In Figure 1, we see a three-sided polygon tapering off toward the bottom and flaring out at the top.[1] If this three-sided figure is opened to show its three faces, it would appear as in Figure 2.

Side 1 represents our universe

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[1] Adapted from an unpublished working paper produced at the American Association for the Advancement of Science Conference on Science Programs for the Elementary and Junior High School, Cornell University, Ithaca, New York. 1962.

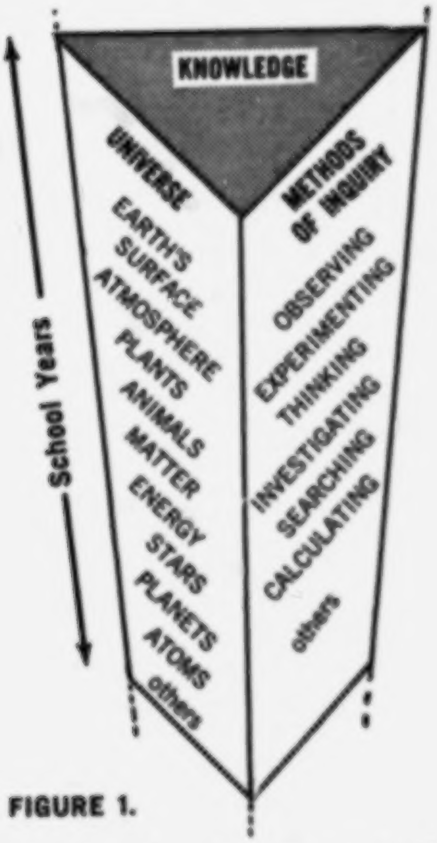

KNOWLEDGE
UNIVERSE
METHODS OF INQUIRY
EARTH'S SURFACE
ATMOSPHERE
PLANTS
ANIMALS
MATTER
ENERGY
STARS
PLANETS
ATOMS
others
OBSERVING
EXPERIMENTING
THINKING
INVESTIGATING
SEARCHING
CALCULATING
others
School Years

FIGURE 1.

which is the subject matter of our study in the natural sciences. It includes objects and forces and phenomena. However, the universe and things in it are *not* science. They are simply objects and forces and phenomena. These things can be grouped and organized in various ways for purposes of study.

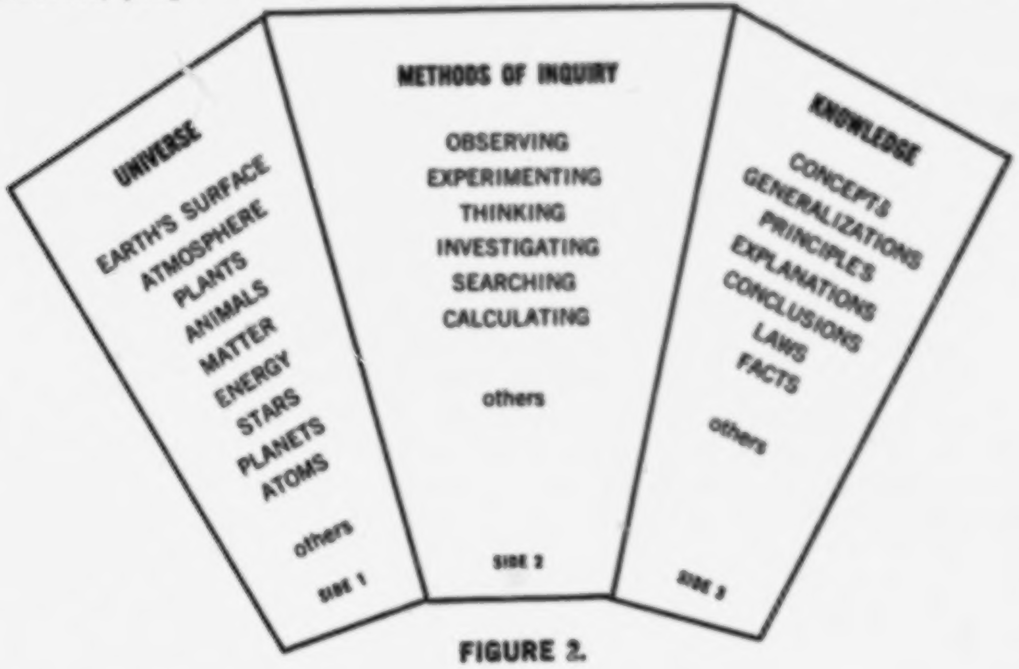
When we begin to study, to investigate, and to inquire into things in the universe, then science appears. Side 2 of the model represents some of the ways people go about investigating their world.

As a result of investigating the universe, people develop knowledge about it. Some of this is scientific knowledge which we may classify as concepts, principles, laws, and facts, for example. This knowledge is represented by Side 3 of the figure.

## Only a Model

With this model before us for purposes of discussion, (no model can *be* a science curriculum) we can visualize and think about the minimum requirements of a science program in the elementary school. Most important, the model suggests that our program must thoughtfully embrace a total concept of what science is. It is a study of the universe by methods that yield valid and reproducible knowledge. Reference to our model suggests a number of more specific considerations.

*a.* The universe is all around but how it is organized for study and what topics, questions, or areas are selected at a particular time is a matter of choice. Since everything cannot be studied at once, choices do have to be made. Though our model does not tell us this, it seems reasonable to believe that a variety of different choices may help children equally well to gain an adequate understanding of basic laws, principles, and concepts. For example, curriculums in some schools may focus on developing the concept of *variety* through study of "plants" and "rock forms" while another school system may organize such learning around "astronomical bodies" and "animals." To help children develop an understanding of the concept of *interaction*, some schools may organize learnings around "forms of energy" and "plant growth" while another may use "atmosphere" and "geologic changes" for this purpose.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CONCLUSIONS
LAWS
FACTS
others
SIDE 3

FIGURE 2.

## Concept Development

*b.* The scientific knowledge which children learn may appear in different forms—as generalizations, principles, facts, conclusions, laws. Year by year children develop a more comprehensive set of concepts which they use as intellectual tools in interpreting and understanding new phenomena or problems. Keeping the focus on concept development enables curriculum planners and the teacher, in particular, to make judicious selection of the aspects of the environment to study so that there is not a compulsion to try to "cover" all aspects of our universe each year, or indeed year after year.

*c.* Helping children grow from less mature to more mature "practitioners" of the methods of inquiry is an inherent part of science teaching.

It is at this point that the temptation is great to insist that children should continuously have experiences doing the kinds of things scientists do.[2] If we recognize that children are not studying science primarily to become scientists and that science teachers may use a variety of methods and materials not necessarily used by scientists, then it seems safe to say that in good science teaching children should make inquiries and investigations, should make descriptions and explanations, and should make predictions. It might follow that teaching which denies children a variety of opportunities to "be like scientists" is neither science nor science teaching.

In this way of thinking about science teaching, the teacher has day-to-day responsibility for involving children in behaviors that are characteristic of scientists at work. Side 2 of Figure 2 shows some of the behaviors or activities of scientists. Lest the kinds of behaviors we refer to seem few, remote, and unidenti-

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[2] An opposite point of view is developed by Derek de S. Price in an article, "Two Cultures—and One Historian of Science." *Teachers College Record*, Columbia University, April 1963. pp. 527-535.

## CLUE WORDS

#### Knowing

Observes
Identifies
Describes
Gathers
Accumulates
Counts
Looks
Sees

#### Manipulating

Measures
Selects instruments
Computes
Demonstrates
Balances
Weighs

#### Applying

Classifies
Assigns
Defines
Associates
Arranges
Distinguishes
Organizes
Estimates
Equals
Sorts
Plans
Compares
Concludes
Experiments
Controls
Ponders
Groups
Decides

#### Creating

Hypothesizes
Induces
Deduces
Speculates
Analyzes
Selects data
Designs experiments
Reflects
Proposes
Criticizes
Conceives
Invents
Guesses
Comprehends
Doubts
Incubates
Predicts
Estimates
Explains
Appreciates
Infers
Abstracts
Synthesizes
Formulates
Interrelates
Generalizes
Forecasts
Extrapolates
Interpolates

#### Evaluating

Ponders
Rejects
Accepts
Believes
Disbelieves
Pools data
Recognizes errors
Equates
Distingushes
Questions
Doubts
Verifies
Decides
Interprets
Criticizes
Transposes
Generalizes
Controls variables

#### Communicating

Tabulates
Graphs
Writes
Speaks
Reports
Explains
Teaches
Informs
Charts
Reads
Debates
Argues
Describes
Demonstrates
Compares
Questions
Instructs
Plots
Draws

fiable, we report here a longer list[3] of clue words that suggest how rich is the array of possibilities.

*d.* The science curriculum must enable children at every level to build on their present experience and knowledge of science, always deepening and broadening their skills of inquiry and their understanding of concepts. The experience of each child must grow and expand as he explores new areas of the environment and deepens knowledge in old ones.

### Attitudes and Objectives

Let us return to our polygon again and view it from another side. (Figure 3.) Other implications for a good science program can be deduced from the model. Perhaps the reader will attempt to enumerate additional implications. Do you see a place for considering attitudes and predispositions about science? Do you see implications for statements of objectives and purposes for teaching science?

Does the model serve as a guide for evaluating specific science activities? Let us try it on the activities described earlier — the children bouncing the rubber ball and measuring shadows—and begin to make a judgment about their potential value. Answers to questions such as the following are pertinent:

1. Did the activity involve the children in describing or explaining some phenomenon?
2. Did the children collect original data from which to draw conclusions?
3. Did the children organize and communicate about the data in useful ways?
4. Did the children have opportunities to speculate and predict?
5. Did the experience relate clearly to development of a major science concept?
6. Were some questions raised that provided stimulation for further study?

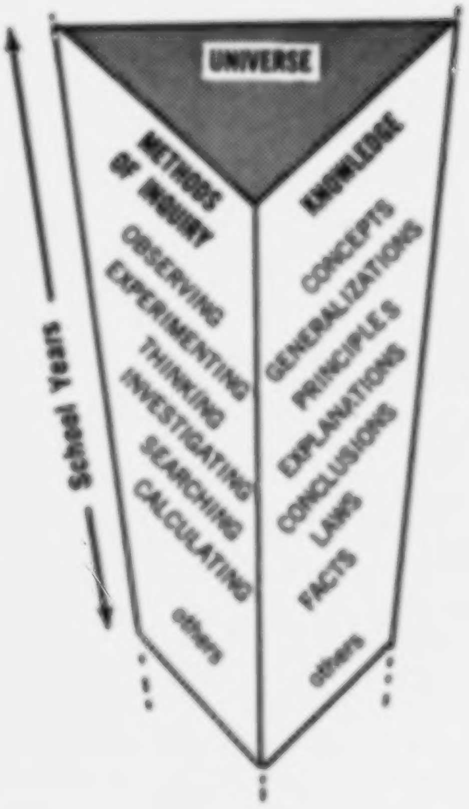

FIGURE 3.

If the answer to most of these questions is yes, it is probable the science experiences in question are making a positive contribution to the science education of the children engaged in it.

### In Summary

This article has attempted to suggest that an understanding by teachers of what science is, particularly in terms of knowing what scientists do, is essential in developing the science curriculum or course of study. A rich science program involves children in activities that encompass the entire spectrum of ways of investigating the environment used by scientists. The effective science curriculum is planned so that children's learning activities are focused on gaining understandings of selected concepts as intellectual tools for dealing with new problems. At every level of school, children's insights and understanding of science concepts and methods should be deepened and broadened if the science program is to make its fullest contribution to the education of children.

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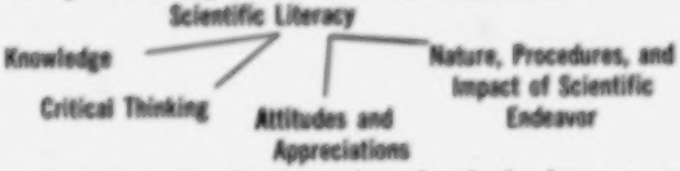
[3] Based on an unpublished committee report of The American Association for the Advancement of Science Conference on Science for the Elementary and Junior High School, Cornell University, Ithaca, New York. 1962.

# Editorial . . .

A recent conference in which I was privileged to participate impressed me once again with the key role—and the responsibilities—of those who are involved in the process of education in science at the elementary school level. The conference group of about 15 persons included professional scientists in the fields of biology, geology, physics, chemistry, and engineering; professional educators from the elementary, secondary, and collegiate levels; and two laymen (non-scientists, non-educators). The task of the conference was "to identify and specify what it is that is important to be taught and to be achieved in science as part of general or liberal education for the total U. S. population." In due course, a project may be undertaken to assess educational progress of individuals at the ages of 9, 13, 17, and 30.

The first big agreement among the conferees was that general education in science should aim at developing scientific literacy as far as possible with as many people as possible. The task then became one of spelling out what it means to be literate in science in today's world. And very quickly the group agreed that this must be taken to mean not only *knowing* but also *doing*. A person who is truly literate in science, they said, must display this quality through behavior. Consequently, the general design or plot of what is important to be taught in science, as agreed to by this particular panel, could be diagrammed:


Scientific Literacy
Knowledge
Critical Thinking
Attitudes and Appreciations
Nature, Procedures, and Impact of Scientific Endeavor

In the study of science in school, the important knowledge will come mainly from the fields of physics, chemistry, biology, astronomy, and geology (including meteorology and oceanography). The learnings will range from action experiences to simple facts and vocabulary and on through principles, laws, theories, and models to the large, integrative, conceptual schemes (or "big ideas") of science.

In the realm of critical thinking, it would seem important to help pupils develop their abilities to use and apply their knowledge in practical situations, to use symbols and numbers in their thinking, and to interpret data and to reach justified conclusions. They should be helped to distinguish among facts, assumptions, hypotheses, and unfounded beliefs and to read science-related materials with comprehension, along with the development of still other skills and abilities.

Significant elements among desirable attitudes, appreciations, and understandings of science would include, among others, an awareness of the role of observation and a functional feeling of the relationships of science to health, conservation, and safety. There would be developed some insight into the reciprocal relations between science, engineering, and technology, and a realization of the historical development of science in changing social climates.

By now you may feel that we have gone up into the clouds and are miles away from elementary school science. Not at all. On the contrary, that is precisely where teaching for *all* of these aims must be started. Children at checkpoints age 9 and age 13 are mostly in elementary schools. Their education in science cannot wait until the junior high school years. This point the conference emphasized over and over again. Moreover, elementary science that is only or mostly a series of disconnected lessons on weather, magnets, or whatever happens to be of current interest, or that consists only of reading about science in books, will be inadequate for all of the above purposes.

This is why K-12 curriculum planning for the total school system is so important. Objectives other than sheer knowledge must be clearly recognized, defined, and taught for, else they may get only lip service and come out poor seconds in achievement. Opportunistic, incidental science teaching in elementary schools is likely to contribute but little to the accomplishment of the large, long-range goals. To be most effective, lessons must be planned with purposes related to specific objectives and with consideration of what has gone before and what is to come, both for the learner and for what is being learned. Testing and evaluation must be as broad-range and as comprehensive as are all teaching objectives.

The individual teacher who takes these viewpoints seriously will find them tremendously challenging in posing reasons *why* science should be taught (and therefore *what* to teach) and also extremely useful as guides for personal performance. Elementary classroom teachers are being asked increasingly to teach science; they have available more facilities and better equipment than ever before; consultative help to get the job done is being provided increasingly; curricula are being improved. But, the glue of a philosophy for education in science to bind these elements together and to give direction to effort to the elementary science program is essential before teachers can hope to contribute to scientific literacy among future 30-year-olds.

**Robert H. Carleton**
*Executive Secretary, NSTA*

# Communication
## —A Goal of Elementary Science Teaching

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WHAT we today call *science* is based essentially on efficient communication—one person relating his experience to others in terms that enable them all to have a similar experience. An example contrasting inefficient and efficient communication will serve to make this point clear.

I see a building and describe it to you as being very large and graceful in design. Even if you were standing beside me while looking at the building, you might disagree with me on the "largeness" of the building or on the gracefulness of its design. What is more, even if you *were* to agree with me, *your* concepts of largeness and gracefulness would differ from mine. We might both be unaware of these differences and be under the illusion that I was communicating something to you. This would be inefficient communication.

*However*, if I describe the building as being eight stories tall and extending 500 feet along Washington Avenue between Third and Fourth Streets, you can count the number of stories and measure the width of the building, thus either confirming or denying my description. If you deny it, I can test your denial by recounting the stories or re-measuring the width of the building. We are thus bound eventually to reach an agreement. This is efficient communication—the kind of communication that has advanced science and technology.

As another example, suppose a chemist, writing up an experiment, states in his report that he used "concentrated sulphuric acid." Or suppose a biologist reporting an experiment states that he used "red worms." Neither report would be acceptable for publication in reputable journals of chemistry or biology. Why? Because one of the primary purposes of publication in science is to enable others to perform the same experiment to compare and verify the results. The "concentrated acid" used by our chemist may have been a 70 percent solution of the acid. Another chemist repeating the experiment may use an 80 percent solution which he justifiably considers "concentrated"; and, therefore, he gets different results. In other words, the communication of the first chemist to the second chemist was not sufficiently precise to enable the latter to obtain similar results.

Turning to the biologist in our example, what does he mean by "red worms"? There are red flatworms, roundworms, and segmented worms. In fact, there are hundreds of species in each of these groups. Suppose another biologist tried to repeat the experiment and used *any* red worm. The chances that he would be experimenting with the same kind of worm as was used by the first biologist would be small indeed. Therefore, there is every likelihood that he would get different or even contradictory results. No amount of argument could ever resolve that the results of one experiment were "right" and the others "wrong." In fact, both experiments were performed producing "right" results; but the biologists may not realize the inconsistency and continue arguing. With inefficient communication no *science* of biology would ever have arisen.

### Classroom Activities To Improve Communication

The ability and predilection to communicate one's experiences to others is inborn; but the ability to communicate *efficiently* must be learned. What kind of *experiences* can a teacher contrive for a young child in order that he may learn to communicate with precision? Some suggestions are experiences with:

1. *Sizes of objects*—comparing and measuring lengths, areas, volumes.

2. *Properties of objects* (properties that can readily be perceived)—describing color, shape, texture, symmetry, flexibility, and hardness and classifying sets of objects on the basis of such properties.
3. *Objects that are undergoing change*—detecting and describing "new" properties as they emerge, determining properties that persist. (For example, the weight of an object persists no matter how its shape is changed.)
4. *Positions of objects*—describing position relative to other objects or to reference lines.
5. *Duration (time-length) of occurrences*—describing, comparing, and ordering the duration of occurrences relative to some regularly recurrent phenomenon, such as the swings of a pendulum.
6. *Groups of interrelated objects that collectively constitute a system*—identifying those objects that are an integral part of the system and determining and describing the interrelationships among the objects within the system.

These experiences, if properly organized, can serve yet another important purpose in the child's education. Each set of experiences in the above listing can extend and deepen a child's understanding of some facet of the world—his concepts of dimension, space, time, or change. Moreover, in the above-suggested experiences, the child can be led to deal with *quantities*. Thus, he can learn to reason and communicate in the language of mathematics. Counting, measuring, and weighing are used in communication. They are processes basic to any scientific endeavor, and in them science and mathematics are inextricably intertwined.

Treating science and mathematics in primary grades as *communication of experience* has implications not only for the selection of content but also for methods of teaching and methods of evaluation. The implication for teaching methods is that the teaching of both science and mathematics in primary grades must center around *experiences* with concrete things to which the child *does* something. This includes counting, measuring, weighing, and classifying. (The last should preferably involve the child in actually moving the objects from one place to another.) The implication for evaluation is that success in learning should be judged in terms of the child's ability to describe his experience with a reasonable degree of accuracy. His description should include not only "results" but also what he did to arrive at them.

# Effective Teaching Of Science

. . . If research tells us anything about child growth and development, it tells us that good primary school science teaching has as its point of departure an experience centered approach based on the child's own questions and observations in such manner that he is actively involved in the process of inquiry and inference in the exploration of scientific relationships. This statement does not mean that the interests of children are blindly followed wherever they choose to wander. It does mean that the teaching is adjusted insofar as possible to the child's developmental level of inquiry. It means that whether or not the experience is scientific in quality hinges on the degree to which the experience actually challenges inquiry and inference making by the child as he discovers significant relationships; and it means that the cultivation of scientific attitudes is understood by the primary school teacher as a process which, in and of itself, is as important as the immediately measurable product of specific knowledges.

Thus, much of what we know about child growth and development stands in partial opposition to the position of the subject matter specialist who views science only as a collected, systematized body of knowledge to be parceled out in formal demonstrations by systematic presentations of textbook materials. This idea of science as a body of organized knowledge to be assigned to students for testing and retention is an 18th century concept. Rather, many science educators today conceive of elementary school science as a process of coming to comprehend why things happen as they do and how to more successfully forecast effects from causes; *i.e.*, how to make more intelligent choices in our everyday living.

Ironically, the need for scientific training is going to be recognized fairly rapidly; and steps will be taken to help elementary school teachers through such means as better in-service science courses, employment of science supervisors, purchase of better science texts, and provision of more materials and equipment. A severe limitation to the steps mentioned above will result if no similar recognition is given to the concurrent growth of elementary school teachers in child development and learning theory.

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These remarks are excerpts from an article by William D. Hedges and Mary Ann MacDougall, "Effective Teaching of Science in the Elementary Schools of Virginia—A Basic Dilemma." *Virginia Journal of Education*, 56:11. May 1963.

# Strategy for Learning

**HILDA TABA**

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THIS ARTICLE is based on a speech originally presented at the luncheon meeting of NSTA and the Council for Elementary Science International during the 1965 Annual Convention in Denver, Colorado.

From the educational tumult of the past decade, certain trends and patterns are now emerging that promise much more interesting teaching for all of us and more enthusiastic learning by our students. For example, research in education is shifting from laboratory to actual classroom situations. New concepts of learning processes offer clues to better understanding of how people learn. We can even begin to think of "strategies" of learning. Teaching, too, is developing strategies—to fit the newer concepts of learning. There is much here that is of special interest for teachers of science in the elementary grades.

An important effect of the shift to classroom-based research is the new perception of the idea of the unlimited potentiality of human learning—including the learning of those whose abilities we currently do not rate too high. The notion of a fixed IQ is being questioned, and the idea of a "functioning IQ" is developing. While no one pretends to know what the upper limit of human potentiality is, there seems to be a fairly widespread agreement that it is much higher than we have known how to realize. Gardner Murphy's book *Freeing Intelligence Through Teaching* (Harper and Brothers, New York, 1961) offers excellent reading on this subject.

From observations of what happens in classrooms in which both the curriculum and teaching concentrate on developing the use of thinking-cognitive powers, I believe that in twelve years of schooling we could achieve a level of maturity about four years beyond what we now attain. This would be especially true if our techniques of studying learning were refined to include some factors that we do not study now because they seem statistically insignificant. Some of these could well be the "trigger" factors that set off processes which could reorganize the entire approach of an individual to learning. By studying the effects of these factors, we may be able to determine more precisely the effect of certain strategies of teaching. For example, how does a certain strategy affect the learning of individuals who have certain abilities, certain types of social-cultural background, or certain motivational patterns? Such knowledge would be invaluable at all grade levels. We need to be alert to findings in this area and to contribute to such research whenever possible.

Recent studies are also revolutionizing the concept of readiness to learn by shifting attention from what readiness individuals *have* to how to *build* readiness—certainly an area of special interest to teachers in the elementary grades. In the first flush of enthusiasm about readiness studies, the findings that children can learn more and earlier have been translated into programs of acceleration. Eventually, it is hoped, these ideas will be translated into creating more potent learning in depth, rather than merely a more rapid covering of the same ground.

Perhaps the most interesting and productive consequence of the new studies of the teaching-learning processes has been the restoration of a balance between content and process as ingredients of learning. In the past, too much time has been spent on conflict between these two areas. Recent emphasis on analyzing the structure of content clarifies the function of the different levels of content in curriculum, in teaching, and in learning. We are analyzing more clearly the processes of learning.

Today, we can identify more precisely the four targets of learning: knowledge, thinking, attitudes, and skills. We need to recognize that only the objective of knowledge can be implemented through organizing curriculum content. The other three depend upon process or the kind of learning experiences that are made available to children. For example, an objective such as thinking has remained in the realm of "pray and hope," because almost anything from daydreaming to inventing the concept of relativity could be, and has been, classified as thinking. This lack of analysis of what constitutes thinking has naturally resulted in uneconomical and ineffective teaching and learning of "thinking." It was too easy to assume that thinking is an automatic by-product of mastering "a subject matter" or of a "natural ability for it." True enough, a small percentage of children did learn some things on their own. Now that all kinds of children remain in school longer, we have an obligation to help all children learn to think.

Because of an inadequate behavioral analysis of thinking as an objective and ingredient of learning, we have relied on accumulating descriptive knowledge in order to enable learners to "think with it" later. Our curriculum in many areas, and especially so in the social studies, has been extremely descriptive. It has called for the same level of thinking, no matter what shifts have been made in content at successive grade levels. These shifts in content have not always been accompanied by systematically escalating the opportunities (or demands) to apply more complex and abstract modes of thinking.

We need to develop categories of the processes of thinking which can be learned and taught. The study of thinking in elementary school children attempts to do this.[1] It deals with three cognitive tasks: (1) concept formation, or the organizing of specific information into conceptual systems; (2) interpretation of data, or the inductive process of developing generalizations and inferences from specific data; and (3) the application of principles and facts, or the deductive process of using knowledge to explain unfamiliar phenomena, to predict, and to hypothesize. These are learnable and teachable targets, because each represents a cluster of skills that can be identified and taught. They are surely especially pertinent to the teaching of science in the elementary grades. In fact, the science teacher should feel particular responsibility for developing these skills. Let us look briefly at each of these targets.

*Concept formation* involves essentially a way of putting unorganized information into some kind of mental filing system by grouping together an array of dissimilar objects or events on the basis of some common property that they possess, such as grouping together climate, weather, altitude, and topography, because all represent some elements of climate.

*Interpretation of data* is essentially a process of evolving generalizations from an analysis of concrete data. This is an inductive way of processing data and making inferences from the data. It involves the ability to go beyond that which is directly given and to arrive at a larger meaning, such as putting together the data on species of animals in a particular area and the data on water and vegetation in the same areas and inferring that generally certain species of animals are found in certain types of environments.

*Application of principles and facts* to new situations involves a deductive sequence. It starts when either a problem or a set of conditions is presented and hypothesizing regarding the possible solutions or consequences is required, such as asking students who have studied nomadic life in a desert to hypothesize what changes would occur in the way of life in the desert if water became available. It also involves a support or verification of these hypotheses and predictions by the application of relevant factual knowledge or generalizations, such as that the presence of water makes possible the growing of crops and, therefore, also a form of settled life and growth of cities.

Each of these cognitive tasks involves several levels of overt activity and of covert mental operations. Therefore, there must also be corresponding teaching strategies which elicit these processes. The three levels of the three dimensions of the teaching-learning process are shown in the chart on the left.

### Concept Formation

| Overt Activity | Covert Mental Operation | Eliciting Question |
|---|---|---|
| 1. Enumeration and listing | Differentiation | What did you see? Hear? Note? |
| 2. Grouping | Identifying common properties, abstracting | What belongs together? On what criterion? |
| 3. Labeling, categorizing | Determining the hierarchical order of items; super- and sub-ordination | How would you call these groups? What belongs under what? |

### Interpretation of Data

| | | |
|---|---|---|
| 1. Identifying points | Differentiation | What did you note? See? Find? |
| 2. Explaining items of identified information | Relating points to each other<br>Determining cause-and-effect relationships | Why did so-and-so happen? |
| 3. Making inferences | Going beyond what is given<br>Finding implications, extrapolating | What does this mean? What picture does it create in your mind? What would you conclude? |

### Application of Principles

| | | |
|---|---|---|
| 1. Predicting consequences<br>Explaining unfamiliar phenomena<br>Hypothesizing | Analyzing the nature of the problem or situation<br>Retrieving relevant knowledge | What would happen if . . .? |
| 2. Explaining, supporting the predictions and hypotheses | Determining the causal links leading to prediction or hypothesis | Why do you think this would happen? |
| 3. Verifying the prediction or hypothesis | Using logical principles or factual knowledge to determine necessary and sufficient conditions | What would it take for so-and-so to be true or probably true? |

## Some Principles For Strategies of Learning

Several theoretical principles underlie the identification of these skills and especially the formulation of teaching strategies for helping students master them.

1. *Learning is a transactional process.* An individual organizes whatever he receives by way of information, from whatever source, according to his current conceptual system. This system may be faulty, partial, productive, or unproductive. For example, in his inquiry training, Suchman shows a filmed "episode" in which what appears to be a plain metal blade is put over a flame. The blade bends downward. The students tend to interpret this phenomenon in terms of the concept that metal softens with heat and therefore bends downward. They are, therefore, baffled when the same blade bends upward when it is

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[1] Hilda Taba, S. Levine, and F. F. Elzey. *Thinking in Elementary School Children.* Cooperative Research Project No. 1574. U. S. Office of Education, Washington, D. C. 1964.

turned over and inserted into the flame again.[9]

Or, the third graders who see in a film a girl in a jungle village putting the coins she received from the sale of carved figures into a pot and then burying it in the floor of the hut may interpret this act as "keeping the money safe from baby sitters," because this is part of their concept of reasons for keeping money safe, inappropriate as it is to the jungle situation. In a sense, then, an individual "remakes," or reorganizes, reality according to his conceptual scheme. The information does something to the individual, and the individual does something to the information.

To aid students acquire increasingly more productive conceptual systems for organizing information, we need to devise learning-teaching strategies designed to help them learn to organize knowledge and not just present them with organized knowledge. One important aspect of these strategies is to stress the asking of questions instead of the giving of answers. The types of questions the teacher asks determine what students can or will be allowed to do.

2. *The learning of cognitive skills is a developmental process.* Each cognitive task involves a series of hierarchical skills that represent sequential steps in mastering the task. Each preceding step is a prerequisite to mastering the next one, and each successive step should capitalize on what preceded. The development of cognitive skills is not instantaneous learning. Each subsequent step requires the use of more complex and more sophisticated operations than did the preceding step. The success with each subsequent step depends on the mastery of the cognitive operations involved in the preceding one.

The concepts themselves are hierarchical in the sense of representing different degrees of complexity, abstractness, and generality. This introduces still another developmental sequence: that of combining concepts of a lower order into those of a higher order.

In an ideal overall sequence, one would rotate tasks which require assimilating new information into an already established conceptual organization with tasks that require a reorganization and stretching of that scheme.

3. *Maturation of learning requires escalation both of content and of cognitive processes.* The planning of learning experiences to promote thinking of this type requires planning on two tracks. One is the sequence and escalation of the basic concepts, ideas, and the required information. The other is the sequence and the escalation of the processes by which information is organized and used. These need to progress together; the neglect of either may prevent or hinder the development of autonomous thinking. Sequences must be planned for both content and mental operations. If not, the pacing of learning is likely to be faulty in the sense that either more or less is required than is possible for the student. The result in the first case is the loss of the autonomy of student thinking, because the student must revert to passive absorption. In the second case the students are bored because the performance required represents repetition of concepts and skills which are already mastered.

### Strategies of Teaching

What strategies of teaching should the teacher apply for this type of learning? First, the teacher needs to construct for himself two sets of cognitive maps by which to guide the process of learning: (1) the map of the content topics, of the dimensions of the topics, and of the basic ideas and concepts that the study of these topics is to produce, and (2) of the nature of intellectual skills involved and of the ways in which these skills are mastered.

Second, teachers need to change their role from the customary answer-giving to question-asking. Cognitive operations are stimulated only as the students are required to *search* for answers and to invent and discover the processes by which to deal with the tasks proposed by the questions.

Third, such a concept of learning introduces a different approach to handling content topics. The direct emphasis is not on "covering" a quantity of specific content but on sampling judiciously the specific instances which are valid examples of certain basic ideas and concepts. These instances must then be explored in sufficient detail to make it possible for students to "discover" the basic idea, generalization, or a concept. A teaching strategy which leads to mastery of powerful inductive generalizations and the necessary application of the corresponding skills is teaching for transfer, because transfer can occur only through the mediation of generalizations.

If these cognitive processes are learned in an interactive process, such as classroom discussion, students have a new source of learning new modes of thinking. In an interactive classroom, students are aided in extending their models for thought processes by "taking off from each others' shoulders," so to speak.

Finally, teachers need to understand and to accept the fact that it takes both time and practice to acquire new skills in thinking. This is especially true when preceding instruction has cultivated habits which are inconsistent with the processes required in thinking.

However, the results in our study of thinking suggest that, given adequate teaching strategy and a curriculum design which facilitates the stepwise development of concepts and ideas, even a student who is considered a "slow learner" will learn to master the higher levels of cognitive skills. All students make great strides both in the mastery of essential knowledge and in the mature use of reasoning power which is considerably beyond the level usually attained. At first the pacing will be slow for all because of the additional task of learning cognitive skills. Later the progress in both content mastery and thinking is cumulatively accelerated.

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[9] J. R. Suchman, *The Elementary School Training in Scientific Inquiry*, Illinois Studies in Inquiry Training, Title VII, Project No. 216, U. S. Office of Education, Washington, D. C. 1962.

# Science Experiences And Kindergarten Children

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To say that science teaching must go beyond the descriptive is to repeat something which has been said many times before. Children do come to kindergarten with a great deal of descriptive information about:

animals (domestic, wild, and lower phyla);
wind and its ability to move things;
the seasons, but not their causes;
weather, in a descriptive sense;
magnetism, what it can do;
anatomy of plants; and
science apparatus, to a lesser degree.

Boys and girls have different abilities, of course, but a number of the children could adequately describe the majority of the items listed above. Thus, it could be interpreted that many of our young boys and girls have had some experience with a wide variety of materials and phenomena which could be grouped under the heading of science.

One of the interesting approaches used by young children when attacking a question or problem with which they have had little or no experience is their ability to make up names for objects or processes "on the spot." These names usually have to do with the function of the item in question. For example, when confronted with a two pole, double throw knife-switch one child called it a "turner offer"; another child when asked what the stem of a plant was called replied, "It holds the flower up"; yet another, when asked what wind was, fanned with his hand to produce that which he was unable to verbalize.

What does all of this mean? Probably, that we waste a great deal of time talking about names of things, processes, and phenomena when we should be going into cause-effect relationships—even with the very young child. Children seem to reason in much the same manner as adults, but lack only experience and the verbal fluency to put their experiences and hypotheses into words.

It tends to follow, that we as teachers of young children, can do a great number of things to help these boys and girls clarify their concepts and give them the power to induce generalizations from their experiences. Some of the steps which can be taken are as follows:

### 1. Give a more exact meaning to words.

Help children become more exact in their description of events and things. Build on the already present fund of knowledge so that misnomers or the lack of names is corrected. Help the student to enlarge his vocabulary. Children love to use words and use them correctly. Why not call retrofire by the correct name? Boys and girls can, and do, learn correct terminology if they have an opportunity to be exposed to it.

### 2. Clarify concepts.

Misconceptions about such things as seasons, the weather and its causes, how plants get their food, and how magnets work, to mention a few, are quite common. This is probably true because these children have not come in contact with the correct concepts, and have had to relate them to experiences which were real to them. When this happens, children many times resort to causes which are relegated to magic and the supernatural.

Clarification of concepts can best be done, not by telling, but by actually experiencing the phenomenon firsthand, if possible. A great number of specific experiences, experiments, or demonstrations will set the stage for the child to induce a generalization concerning the process or concept in question. Children love to manipulate objects and, with guidance, can learn a great deal from this type of experience.

### 3. Provide many experiences in many science areas.

Children have had, before entering kindergarten, experiences in many areas of scientific knowledge—astronomy, electricity, magnetism, the animal kingdom, weather, geology, and even electronics, to mention a few. To limit the science experiences of kindergarten children to one or a few areas would be a mistake.

It would be quite difficult to find an area in which children would not be interested. With materials such as the excellent trade books which can be read to children; filmstrips; films; science materials which can be manufactured from everyday household items; and the ever present natural phenomena, science can become an exciting, highly motivating field of exploration. Children have "built-in" interest and will be quite eager to look at, feel, manipulate, smell (and sometimes, even taste), as well as talk about the items which are made available to them.

*With "built-in" interest, the child's curiosity is easily motivated.*

As was mentioned earlier, the chief danger we face as teachers is that of verbalizing. This is particularly so for the teachers of very young children. We know from research that these children need concrete experiences; many of them, so that the concepts which are being developed can be structured from ideas which have been given meaning through experience.

There are no data available which would *prove* that one topic or area should be stressed more than another. There are many ways of determining what may be studied, but the keynote should be to touch on as many areas of science as is feasible with your particular group of children. In short, know your class!

### 4. Show cause-effect relationships.

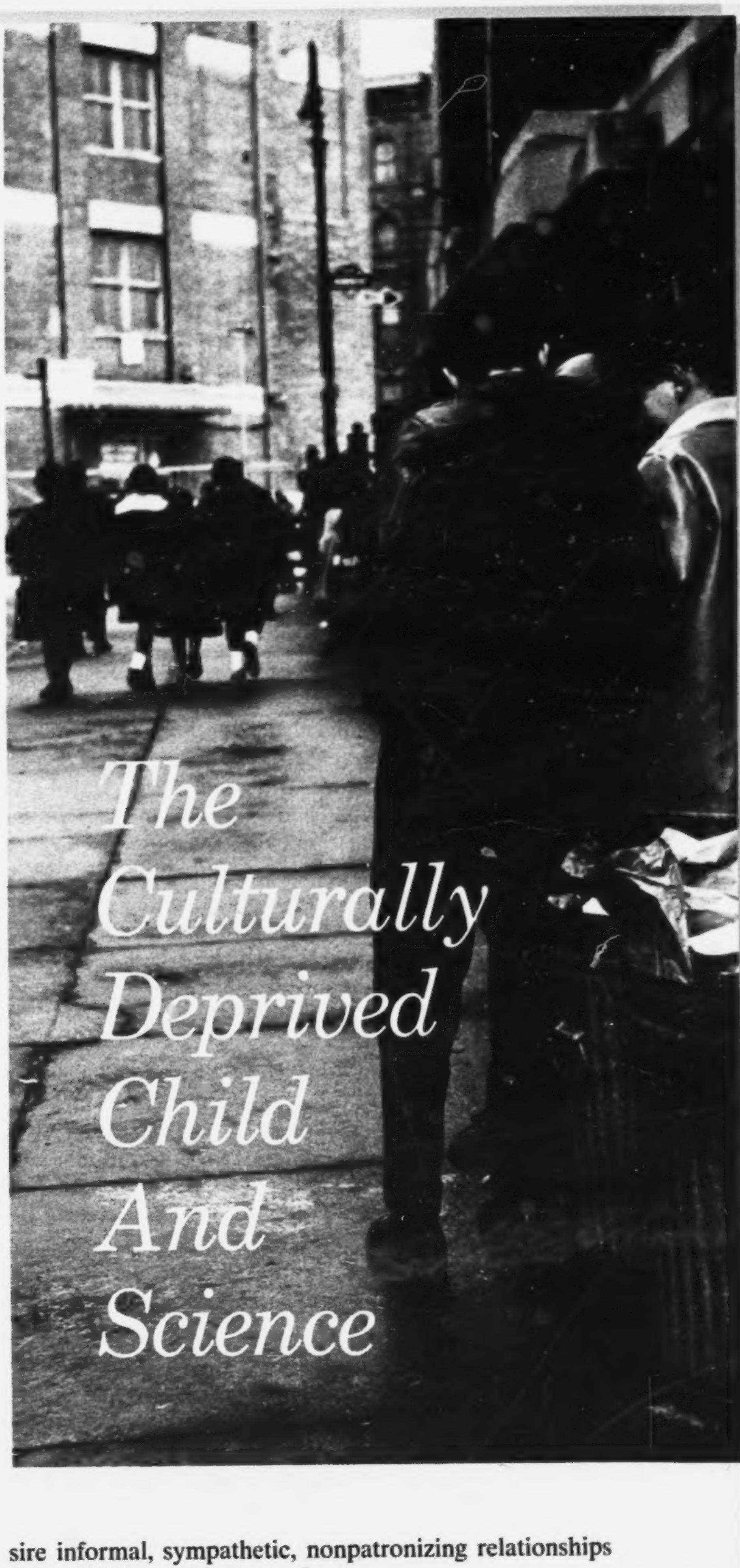
Start this work with a sophisticated concept such as the causes of day and night. Most assuredly kindergarten children will not be able to fully comprehend why our planet is held in a somewhat complex and, relatively speaking, stable orbit. However, I doubt very much if there are many children of that age who cannot understand the demonstration of a light source shining on a rotating globe suggesting day and night.

Thus, in this and many other ways, children can be brought to the point of actually understanding reasons why things happen. If children are initially taught in terms of cause-effect relationships and not just facts, a great service will be rendered them. The type of thinking which will be applicable and necessary in every field of endeavor is basically that which is used to help solve problems.

### 5. Know the children.

Finally, as the backgrounds of children vary widely, it is imperative for us to know as much about each child as possible. Practically every child can contribute something to the kindergarten science program. Science provides a wonderful vehicle through which children can be drawn into a group discussion. The pet turtle which is owned by an extremely timid or quiet youngster may be the perfect opening to bring him into the group. On the other hand, the excessively verbal child can be brought to the point that what he is saying is important, if he can talk about something in which he has some interest or knowledge.

In the final analysis, the vigor of the science program in the kindergarten depends upon the teacher. The best course of study, the finest materials, and a wide variety of multi-sensory aids are of little or no value if not employed wisely. A teacher, who is alert to the group and is willing to go beyond just talking about science, can develop a wonderfully exciting program for the five-year-old. It can and will be wonderfully exciting for her too!



# The Culturally Deprived Child And Science

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Educators have always had the problem of adapting the curriculum to the needs of children with special problems. Today teachers throughout the country, particularly in urban areas, are being confronted in ever-increasing numbers by the special problem of the culturally deprived or disadvantaged child. In New York City, it is estimated that 225,000 out of 573,000 elementary school children and 75,000 out of 186,000 junior high school pupils are in that category. Coupled with the disadvantaged or culturally deprived child is the non-English speaking child. About 11.5 percent of the entire elementary school population of New York City speak English haltingly or not at all.[1]

What are some characteristics of these children? In working with them, one quickly becomes aware of their general lack of achievement in the basic academic skills of reading, writing, and arithmetic; their general low self-image; and their lack of interest. Then one becomes aware of their limited experiences. What we tend to take for granted in youngsters—that they are familiar with gardens, pets, automobiles, trains, bicycles, elevators, and the country—is not necessarily true for these children. Indeed, many have never strayed from their own neighborhood or block, even though they may live in a city with many places to go and things to do.

What are some of the conditions that cause cultural deprivation? Although poverty may not in itself be a cause, most culturally deprived children come from poor areas. Many come from broken homes or from families with deteriorated social standards; many come from areas where there is conflict between their own existing subculture and the standard American middle-class culture. Then, too, these areas may contain a constantly changing population with families moving in, staying awhile, and moving away again. The youngsters may have no roots, no feelings of loyalty, or no sense of responsibility to the community.

Teachers need orientation to work with these children since the children's expectations contrast sharply with the teaching and therapeutic processes which the teacher is normally trained to use. For example, these children desire authority and direction rather than training in self-direction; they desire action rather than introspection; they desire structure and organization rather than a permissive situation; they desire simple, more concrete, scientifically demonstrable explanations rather than symbolic, circuitous interpretations; and they desire informal, sympathetic, nonpatronizing relationships rather than intensive ones.[2]

These desires and expectations of the disadvantaged child are positive elements upon which a functional and developmental curriculum can be built. Frank Riessman, in his book *The Culturally Deprived Child,*[3] strongly advocates such an approach. His observations identify other elements which have a direct bearing on the development of curriculum for these children. These are: ability in abstract thinking, but at a slower rate than middle-class children; skill in nonverbal communication; greater achievement when tasks are motor-oriented; and greater motivation to tasks which have tangible and immediate goals.

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[1] *Higher Horizons Progress Report.* Board of Education of the City of New York. January 1963.

[2] Frank Riessman. *Some Suggestions Concerning Psychotherapy with Blue Collar Patients.* Mobilization for Youth and Department of Psychiatry, Columbia University, New York City. Unpublished Mimeographed Paper. 1963. p. 4.

[3] Frank Riessman. *The Culturally Deprived Child.* Harper and Row, New York City. 1962.

An elementary science program for such children must be based on the positive elements of the characteristics, environment, and expectations of these children.

### What Are the Features of Such a Program?

*An elementary science program must be based on the pupils' environment.*

Children are concerned with the world about them; the sound of bells, thunder and lightning, automobiles, airplanes, trees, birds, and their own bodies. Disadvantaged children are no exception; however, their own world may not be the same as their teacher's world. To the teacher, larva, pupa, and butterfly are part of nature; to the pupils these may be meaningless because they may never have seen these things. Skyscrapers, concrete, and alley cats are more meaningful to these children than the Grand Canyon, sedimentary rocks, and protozoa. The culturally deprived child's environment is quite restricted, and we must seek from his environment those elements familiar to him and build our program upon them.

It is also important to enlarge the pupil's environment. This suggests that he be given direct experiences through audio-visual materials. A trip to the farm or zoo where the urban slum child can see and fondle farm animals, a lesson on magnetism where he and his fellow pupils can handle many different magnets, or a film which shows him what makes night and day are all experiences which enlarge the pupil's concepts about his environment.

### An Elementary Science Program Must Be Based on Real Problems

Children ask questions about their environment and want answers to their questions. Some of these questions are: How does the school bell ring? What makes the light go on? Why do we want to explore outer space? How can we keep food from spoiling? How does the weatherman forecast weather? How does a telephone work? How can my skates roll more easily? What makes a car stop? Whereas many children frequently obtain the correct answers to their questions from parents or from books, the culturally deprived youngsters generally do not. Their parents are not able to help them and they are not able or motivated to help themselves. They must rely on the school for the correct answer, or else be satisfied with misinformation or no answer. The implications are clear. The teacher must gear her program to help these children find answers to questions about their environment. Indeed, the teacher may need to help the children verbalize questions which their environment has led them to submerge. Questions, such as those listed above, could and should serve as the aims of lessons in elementary science. By basing the aims of her lessons on real problems, the teacher can capitalize on pupils' interest and compensate for the learning they should, but do not, receive at home.

### Elementary Science Should Not Depend on Reading or Other Academic Skills

A major weakness of the disadvantaged child is lack of achievement in reading and other academic skills. This lack of achievement in reading probably accounts, in large measure, for lack of success in other curriculum areas which depend on reading. If an elementary science program is to be successful, then the pupils must feel that they can succeed in science. I conceive of elementary science as a truly "democratic" subject—democratic to the extent that every child can participate in, and get a feeling of, achievement and success from it. Therefore, it is important that activities be so chosen that they do not discourage children. One way to do this is to use children's language skills, other than reading, in the elementary science program. Such skills as listening, speaking, reporting, observing, and note-taking (at the pupil's level) should be encouraged.

Teachers should plan lessons which draw on pupils' experiences, and the conclusions to each lesson should be elicited from the class in the pupils' own language. Audio-visual materials should be used extensively to provide basic information and material for research. Children can use filmstrips with individual viewers just as they would use books. The formation of soil and the operation of the water cycle can be demonstrated more effectively by films than by books.

Although the basic science program should not depend on textbooks, children should have contact with many science books at their own reading level. Thus, instead of 30 books of a basic series of texts on one grade level in a class, it might be possible to have 30 books of many series at different levels. Trade books on many topics at varying reading levels should be available. In this way, children could select those books which they are able to read, and which do not frustrate them.

### Elementary Science Should Reinforce Basic Academic Skills

Although this may seem contrary to what was previously stated, it is not. Elementary science can and should encourage and motivate growth in reading. As these children get a feeling of success from their science activities, they may be motivated to greater achievement. Thus, they can be encouraged to use some of the trade and textbooks that are to be found in the room. Elementary science can provide even more basic reading experiences. Labelling of specimens, models, and charts provide reading experiences, as do captions on filmstrips. In my own experience, at the end of each lesson I ask the children to tell me what they have learned from that lesson. Their own statements are written on large sheets of paper and the pupils copy these in their notebooks. Many weeks later the pupils are able to read their statements, although they may not be able to read at that level in their basal readers. They are able to read their experience charts because they are motivated to learn to read those statements which arise from their own experience. Elementary science is used to motivate these pupils.

A more formal experiment correlating science and reading is being conducted by Richard Kinney, at Public School No. 188 in Manhattan. In this experiment, reading lessons, based on the children's science experiences, are being prepared on three reading levels. The results so far have been encouraging and point to further study in this area.

## Elementary Science Should Afford Children Opportunities to Handle Materials and Equipment

A fundamental concept in teaching elementary science is that all children should have an opportunity to handle materials and equipment. This is especially true for the culturally deprived child since he seems to have greater achievement when tasks are motor-oriented. Teachers, therefore, should provide every opportunity for children to participate in demonstrations and experiments. If possible, there should be enough material so that every child can use the same materials at his seat that his teacher is using at her desk. Kits of materials can be organized which contain, for example, 30 dry cells, 30 switches, 30 bells, and pieces of wire, or 30 sets of different magnets. The materials that are used should be familiar to children. Esoteric and elaborate equipment should be avoided since it may be confusing to children; and assume importance rather than the science concepts being demonstrated. Children should be given recognition for their projects by having their exhibits displayed to other pupils as well as to their parents and to the community at periodic science fairs.

Through proper adaptation of the elementary science curriculum to the needs of this large portion of our children, we may bring about an enrichment of their lives which, in turn, will benefit our entire community. We have, so far, failed to tap America's greatest resources, the creative skills and abilities of all its children. Among these disadvantaged children, there is a large reservoir of future high-level, professional, and skilled personnel, if we learn how to help them realize their potential.

Throughout the country, experimentation with curriculum development for the culturally deprived children, such as the "Higher Horizons Program" and "Mobilization for Youth" in New York City are providing insights into the techniques of teaching such children. Through implementation of our new insights, both society and the child will benefit.

*These sixth-grade pupils were given paper tops as part of an elementary science lesson on color and light.*

# *A Discovery Approach For Developing Productive Thinking*

Experiences that promote methods of inquiry or self-discovery help individuals to meet the needs and challenges of modern times. The preceding assumption has been a guiding principle for teachers, specialists, pupils, and parents who have cooperated in the enterprise of designing a science program for children attending grades one through six in the Laboratory School at Colorado State College, Greeley.

The ways in which scientists think, work, and organize knowledge constitute the methods practiced by children in the process of learning. The primary experiences are those of discovering knowledge through many divergent methods: becoming aware of problems that are defined as guides for self-discovery of ideas; recognizing and testing hypotheses; evaluating data and processes for explorations; forming conclusions; and applying knowledge and method to the solution of new and different situations.

To gain insight into and understanding of the extent pupils can employ the above practices at various age-grade levels, certain investigative procedures have been used. These include the following:

The observations of children's performance were recorded as they conducted their demonstrations, experiments, and creative tasks, checked their hypotheses, and formed their conclusions. The recorded items were later analyzed for methods of inquiry which the children were able to use at various age-grade levels.

Diaries of consecutive class activities were maintained by staff members and by graduate students who were observing the children and who were currently enrolled in professional courses in the teaching of science. These records, when analyzed, revealed certain inquiry techniques which children could use.

Written records voluntarily maintained by interested pupils were analyzed for evidences of discovery techniques or methods of problem solution.

Methods of inquiry employed by pupils who had engaged in creative activities were analyzed for basic learning procedures.

Evidence submitted by tape recordings of class activities was evaluated for significant aspects of critical thinking apparent in children's oral contributions.

Recommendations made by specialists and qualified educators were used to refine the list of behaviors signifying children's abilities to use methods of inquiry.

The above are feasible and effective procedures to determine children's ability to think because they serve as a means for a continuous study of pupil abilities throughout the elementary school program. Consistent observation and the application of definite criteria to evaluate the observations have revealed that children's ability to use self-inquiry methods increases with each age-grade level and occurs in a classroom laboratory where pupils have access to the use of equipment and materials, the out-of-doors, visual devices, and other learning aids. Learning through self-discovery is greatly enhanced by individualized and small group exploration. This practice provides opportunity for pupils to begin with those experiences commensurate with their levels of ability and then progress according to their capabilities. In all laboratory situations, the children are encouraged to become critical thinkers, expert collectors and recorders of data, originators of ideas, proficient users of measurements to collect and test the accumulated information, and appraisers of assumptions that condition the accuracy and acceptance of conclusions.

## The Procurement of Major Concepts as a Vehicle For the Development of Productive Thinking

Certain unitary or conceptual themes function as structures for organizing the concepts or knowledges of science. These themes describe *the relatedness of the biological-physical world, earth-cosmic environment, growth and development of organisms, the flow of energy and matter through organic and inorganic materials, the ever-changing nature of the universe, and life on the earth.* Children's questions which have

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persisted over the years and written records of problems investigated have been collected, examined, and used to procure a workable list of concepts for the program. In addition, as new knowledge has been reported by the scientists, science specialists have recommended additions, alterations, and modifications in the original list of concepts. These specialists have cooperated consistently in the development of a science program and have aided in the development of knowledge pertaining to the questions that children have brought to their studies.

### A Learning Center for Children to Gain Insight Into the Objectives of Science

The center for learning is a classroom laboratory equipped with facilities and materials appropriate for children's use. Such facilities are mandatory for a program committed to pupil inquiry. The environment for conducting investigation has evolved from a cooperative enterprise among children, teachers, parents, administrators, and interested friends who recognize the need for materials and tools for achieving quality in learning. Children have had a prominent share in the laboratory's development, for as they have produced demonstrations and experiments, they have needed to make models and devices, collect materials, and create ways to solve problems. This equipment is subsequently added to the stock of learning aids. The out-of-doors environment is replete with an abundance of materials. Because of children's interest in natural phenomena, they bring in many materials which help answer their many questions or they take their questions out of doors to seek answers in nature's vast laboratory.

In addition to actual specimens and equipment, the classroom is equipped with books, pamphlets, magazines, charts, models, bulletin boards, and folders for clippings and pictures. Children share their "fun books" with others, for some have begun to develop their own libraries.

Some materials are arranged on open shelves, others in cupboards labeled, organized, and available to children. To depict the scope of science to children, the room is organized about certain conceptual themes which tend to show the interrelatedness and unity in the universe. These schemes for organization planned and directed by the children vary from year to year: for example, parallel evolution of the earth and life on the earth, flow of forms of energy and use of materials, the new areas of research.

### Discoveries of the Effect of the Program On Children

Children's curiosity and inquisitiveness are forceful instruments for maintaining a high degree of interest. Behavior of this type is nourished and fostered by pupil self-discovery techniques. This uniqueness provides a teacher with a basis for the development of quality learning and, more specifically, quality thinking. Young problem-solvers function best in situations requiring the use of concrete materials from which perceptual learning accrues. As children continue in the science program, the intellectual processes of explaining, comparing, constructing, classifying, and making measurements evolve progressively from grade to grade.

Achievement of the objectives of science is related to the nature and quality of equipment and materials used in the discovery process. An understanding of the nature of science demands materials, if its secrets and meanings are to be revealed. Tools used by a scientist in collecting and verifying data which are also practical for children's use increase both the quantity and quality of learning. Then, too, insight into learning is in direct relationship to the divergent methods employed by pupils such as demonstrations, experiments, interviews with scholars, audio-visual aids, controlled investigations in the environment, and facilities for studying many natural processes.

Children can increase their ability to use inquiry methods. Such evidence has been manifested by the creative activities designed by pupils, science fair activities, and the ways that children continue to work during the daily class activities.

A functional program in science can be obtained when many groups, interested in children's learning, cooperate as a forceful unit: teachers, pupils, science scholars, parents, and specialists in the community. When the children's abilities, needs, and interests are comprehended by curriculum designers, a positive base for structuring a program evolves.

The basic skills of listening, reading, writing, speaking, and arithmetic are essential for communicating and evaluating learning. Making use of quantitative treatment is essential for much of concept learning. This procedure is imperative, since science is largely quantitative rather than descriptive in nature. As children progress through a science program from grade to grade, quantitative treatment of data becomes increasingly imperative in the development of concepts and methods of inquiry.

Pupils, through the total program, gain knowledge and skill in the processes of thinking, such as the discrimination and analysis of recorded observations, formulation and evaluation of hypotheses, quantification of concepts, and organization of defensible conclusions. The product of the processes of thinking is knowledge that involves facts, concepts, and broad generalizations. Both product and process of science develop under laboratory conditions when pupils use a discovery approach to learning.

# TRENDS In the Elementary Science Curriculum

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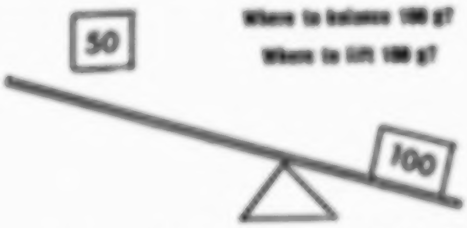
AN ATTEMPT to define elementary science programs for 1970 would be crystal-ball gazing. Even present curriculum development efforts of local school districts, state departments, and National Science Foundation supported projects vary considerably in philosophy. A variation in philosophy naturally results in variation of organization and scope. However, certain identifiable characteristics, or trends, indicate a general course of development for elementary science programs as they continue their evolutionary process of reform and improvement.

The following eight trends that have developed have received the most attention and change as a result of the new emphasis on improving science teaching at the elementary level. They are, of necessity, general in nature and are intended to represent an overall curriculum position rather than individual or localized studies or programs.

1. **Concerning Organization.** Science content is being organized into larger units, samplers, chapters, and kits in order to reduce fragmentation of topics. Material, particularly at the fourth to sixth-grade level, is designed for more "depth study" and does not contain numerous, short units. This trend implies the belief that children are interested in digging and exploiting content more fully as opposed to skimming units at a shallow or superficial level.

2. **Concerning Individualization.** Greater emphasis is continually being placed on individual involvement and participation. Demonstration experiments conducted solely by the teacher with perhaps one or two students are being reduced in number or eliminated altogether. Experiments are being devised that provide for each child (or team) weighing, pouring, measuring, mixing, pacing, and comparing.

The previously important distinction between activities, demonstrations, and experiments has been reduced in lieu of providing an "experience" where the desired problems-questions to be worked by students materialize as a result of the activity. For example, by providing every two students in a class of thirty with a meter stick, individual problem-solving activities are possible while the entire class investigates the same concept—as in the following illustration.



Each student is thus involved with a problem situation by investigating the two questions: (1) Where do you locate the 50 g weight to balance the 100 g weight? and (2) Where do you locate the 50 g weight to lift and anchor the 100 g weight? Each pupil uses equipment and materials helping him to develop manipulatory skills and confidence. Because of firsthand experience with this problem situation, the terms resistance, fulcrum, and weight arm have meaning.

In other situations *each* pupil investigates seed germination, measures precipitation, or paces the distance to the planets as opposed to having the teacher or class representative conduct an investigation. In these kinds of experiences, students truly discover, rather than re-prove or observe that which is already known. In the pupil-centered experiment, the teacher must refrain from "giving away" the answer or outcome until the students have discovered the phenomena of change. She becomes a leader in the "let's find out" process, and in theory rediscovers science. As a partner in learning, the teacher thus becomes more effective in teaching science.

3. **Concerning Content Balance.** Greater emphasis is being placed on earth, space, and physical sciences in contrast to earlier domination of plants, animals, human body, and related life science topics. While there are numerous schematic organizational plans, the following list suggests one plan of how content areas in a modern elementary science program can be organized under three categories. Designating elementary topics as *life*, *earth*, or *physical* science brings elementary science more directly into the K-12 concept of a total program. These three categories have specific meaning to high school teachers of science who have frequently been confused as to what science was taught in the elementary schools.

| LIFE | EARTH | PHYSICAL |
|---|---|---|
| Plants | Earth history | Matter (atoms) |
| Animals | Earth structure | Energy |
| Human Body | Meteorology | Magnetism |
| Micro-organisms | Solar System (universe) | Electricity |
| | Oceanography | Heat |
| | Conservation | Light |
| | | Sound |
| | | Machines |
| | | Rockets-Satellites |

Grade-level placement of these topics is arranged to provide repetition-reinforcement of subject matter with completion of all topics by the end of grade six. Sound, for example, a less emphasized topic than the human body, might be studied only in grades two and four, while the human body might be studied in grades three, four, and again in depth in both grades five and six.

4. **Concerning Scope and Sequence.** Several contemporary experimental programs recognize the need for greater student participation in programs and do not identify or structure their units for specific grade-age levels. This technique offers schools excellent opportunities to develop their own programs and utilize pre-tested materials at levels consistent with the interest and ability of children within their own districts. Development of unstructured science experiences also offers great incentive for individual school districts to organize or modify their own elementary science units.

5. **Concerning Textbooks.** The increased desire of school districts to plan their own programs, coupled with moderate gains in teacher ability and desire to teach science, has reduced complete dependency on the use of conventional science textbook series. However effective the text material, the sole use of a text can force a structured program that limits the scope of topics in the science curriculum. Increasing numbers of schools and school districts are organizing their science programs without science textbooks and are investing their budgets in equipment and library materials which accommodate the versatility and individualization of their curricula.

Totally new activities must be developed where the nature of the activity and the equipment utilized will permit full physical involvement of all students. Increased imagination of authors and publishers to provide other than conventional textbook material will be required to maintain and increase effectiveness in elementary science education.

6. **Concerning Equipment.** The present emphasis on the use of equipment in the teaching of elementary school science assures the development of a wider choice of materials—games, puzzles, kits, records, tapes, and slides. More significantly, the trend toward individualization of instruction and the need for classroom sets of certain items is causing: (1) simplification of present apparatus, (2) cost reduction of expensive items, and (3) creation of new apparatus of simple design. An example of a significant breakthrough was the development of simple microscopes which could be made available to large numbers of students at very low cost. Hopefully, suitable planetaria, aquaria, transformers, meters, motors, and numerous other items will experience the same cost reduction. The expanded NDEA funds and other federal assistance are also reducing financial difficulty for school districts in purchasing equipment, library books, and related material.

7. **Concerning Nature of Content.** The trend toward still greater sophistication of elementary science is evident. Improved instructional methods, improved teacher attitude and competence, effects of television and related media, along with student enthusiasm generated as a result of involvement, will certainly require greater depth of more challenging material.

There is evidence which suggests that certain units, such as machines, transportation, and communication, may be absorbed into larger units. In that they are *uses* of science rather than science, they will lose individuality as distinct units in the science curriculum. The study of time, tides, longitude and latitude, and the seasons should completely transfer to the social studies curriculum.

The final merger of health-safety programs into the science curriculum is being completed with the possibility of adding mental health to the study of the human body. Evidence suggests a more liberal and enlightened approach to both the study of human reproduction and evolution.

8. **Concerning the Emphasis on Measurement.** Increasing importance is being attached to the development of skills in measuring. Student's experiences with measurement lead to the construction of scale models, charts, and graphs and to development of other methods of recording scientific data. The metric system of measuring is being used throughout the entire K-6 program just as it has been in the new physics, biology, chemistry, and earth science programs at the secondary level.

There is no doubt that the elementary science curriculum will change and improve at a faster pace in the future than it has in the past. Progress will be accelerated by the employment of science specialists, the expanded science interests of children, and the increased assistance of the federal government. The interest of elementary educators should unify the teacher-administrative committee mechanism that is essential for curriculum change.

# Our Readers Speak Out . . .

# Teacher Adaptation

**This department of *S&C* is devoted to pro and con discussion and the analytical and critical evaluation of programs, policies, and activities of various organizations, groups, and agencies. Contributions should be directed to issues of general interest, must represent author's opinions and viewpoints, and should not exceed 1000 words. The right to accept or reject statements is reserved to *S&C*.**

**The Editors.**

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"Living things adapt to their environment" is a familiar generalization included in many curriculum guides and textbooks. But "teacher adaptation" to the prevailing situations is not as widespread as one might wish.

Despite the new developments in elementary science teaching the majority of elementary teachers will probably be following the well-beaten path of science teaching defined by the adopted textbook, curriculum guide, and previous custom with perhaps a cautious deviation now and then toward a new idea. "Teacher adaptation" calls for the teacher to be wary of the pitfalls in the well-beaten paths and not only in the new routes! For example:

1. *Regional differences demand "teacher adaptation" of nationally distributed textbooks.*

The topic of "Seasonal Change" (autumn coloration, hibernation, etc.) is prominently emphasized in primary textbooks. "Seasonal Change," as described in some texts, is certainly not experienced in most of the southern latitudes of the United States. Pictures of corn shocks and pumpkins in the field may be appropriate "signs of fall" in Indiana—but not in California, Texas, or Florida. The robin as a harbinger of spring may be suitable in the Northeast—but in parts of the Southwest the robin, if encountered at all, is a winter resident. Yet this writer has seen teachers in a "non-robin" region blissfully following the textbook and listing the robin as a "sign of spring." Snow is inevitably linked with winter—but many southern children have never seen snow while western mountain children may experience it in summer! Teachers need to use illustrations from the environment and not from a textbook inappropriate to the region.

2. *Population movements call for adaptation of curricula to pupil experience.*

Urbanization, insofar as it removes more and more children from nature, has eliminated much of the "direct contract" with rocks, fields, and birds. This means that the traditional units as "How Different Rocks Are Made," or "How Birds Are Helpful to Man" will be difficult to teach in a city setting. In the city, rocks are usually covered by cement and asphalt, the soil is well curbed and retained by park grass, and the bird life is characterized by English sparrows, starlings, and pigeons! For the city teacher who wishes to develop concepts in such areas, it seems imperative to supplement the textbook approach with more than the usual number of visual aids, museum visits, and field trips. Better yet, concepts growing directly out of city experiences may be selected: "City birds may multiply and become pests;" "City buildings show the effects of weathering and abuse."

Authors of children's textbooks are not unaware of the migration to the cities. Therefore, some of the most popular elementary series have included materials on forces, machines, and other materials which are within the realm of the city child. Conversely, this calls for adaptation by the rural and small town teacher. Textbooks by "big city" authors have been found to be very meager in such vital areas as earth science.

3. *Changing times call for changing emphasis in science teaching.*

Just because some topic has "always" been included in the science textbooks does not mean its continuance is desirable. Science teaching will continue to be in trouble if the emphasis is primarily on practical applications rather than basic principles. The steam engine gave way to the diesel locomotive—but the textbooks continued graphic sections on "How the steam engine works." Coal has been superseded by petroleum as the most important energy and raw material source—but in many instances petroleum is not accorded the more than "equal time" with coal that it merits.

Some items traditionally associated with science should be relegated to folklore, or discarded entirely. A prime example here is the groundhog legend, with all the homage that is paid to the prognosticative abilities of this creature on February 2! Why perpetuate the superstition when the animal's prowess as a weather forecaster has long been debunked?

4. *Teacher adaptation calls for continued study of children as well as science.*

Many elementary teachers who have a fear of science seem to think that today's children are born with the accumulated scientific knowledge of the ages. Just because children glibly use a scientific vocabulary does not mean they automatically have correct concepts. A young child's ideas of clouds and stars may be as "primitive" as those of Stone Age man.

Yet the young child's curiosity and exploration of his world are the beginning of science education. As we learn more about the way children think and form concepts, we will be able to guide their learning more effectively. The good teacher, as always, will begin with where the child is, using the environment to best advantage. The teaching materials he uses must be relevant. If a suggested textbook experiment does not make sense to the teacher, it probably will not be meaningful to the child. The awe with which the science textbook is often regarded by timid teachers has certainly not furthered science education.

The elementary science teacher who is willing to venture from the rutted route of textbook and curriculum guide and take a closer look at the child in his actual environment may be in for some delightful experiences!

# Editorial...

The great ideas of a culture are usually transmitted from one generation to another by a process we call education. These accumulated ideas are not only transmitted, but are also interpertated, evaluated, and if possible, improved through the educational process. Schools, through the teachers, act as the agents of interpretation of the culture and its effects upon the individual and society. To neglect any aspect of this process at any grade level is to fail to educate; because, only through this process does man become intelligently competent to continue his search for new knowledge and understanding. The great ideas designated as science have to be treated in this manner as do all other areas of culture. All boys and girls should be exposed to the great ideas of science at their level of maturity. If we expect to improve our culture, we must develop individuals who understand the world they live in and their relationship to it at their level of understanding. To do less than this is to fail in our role as teachers.

One of the responsibilities of the teacher is to help his pupils distinguish between ideas that are science and those that represent the uses of science or technology. At times, this will be very difficult because the two are so interwoven in our lives, but the distinction has to be made. This distinction can only be made if the students are involved in the use of the modes and processes of science. Experiences will have to be provided that involve the students in experimentation, observation, and testing. Only in this way can they learn what these terms mean.

Involvement in activities that lead toward conceptualization of ideas associated with science and their applications help the elementary student understand the culture of which he is a member. This involvement is accomplished only if the teacher knows the nature of the learner under his direction. The teacher in the elementary school must be conscious of the individual patterns of learning of his pupils and seek to understand the purposes of each child for learning. He should also capitalize upon the imagination of children, make provisions for individual differences and skills, recognize that children relate to all aspects of their environment, and that children like to inquire, investigate, and seek answers to problems.

Skills that are important for studying science at any level have to be started and developed in the elementary grades. Pupils should learn to observe accurately and report objectively. They should be encouraged to withhold judgments until enough evidence has been gathered to make an assumption. The proper handling and use of common scientific instruments should be part of the elementary school program. When faced with a new situation, the student should be able to use the skills of science he learned in the elementary grades. All of these skills can be further developed at the junior and senior high school level.

Although there is not one pattern or curriculum, defined as best, for the teaching of science in the elementary school, it is imperative that this area of study be included in the learning experience of every boy and girl.

Donald G. Decker
*Dean of the College*
*Colorado State College*
*Greeley, Colorado*

# Editorial . . .

During the last ten years, much effort and a huge amount of money has been devoted to changing American science education—Resulting, undoubtedly, in rather vast changes. Unquestionably, a good many of the changes have been real improvements. In spite of this demonstrable progress, I have the feeling that very little has been accomplished toward giving all young people improved experiences in science. This is reflected by the low number of school systems which have a well developed K-12 science program in operation in their schools today.

It is true that in almost all school systems today, science has been made a significant element of the instructional program in the elementary, as well as the secondary schools. Thus, a student is likely to have some science instruction at each grade from the kindergarten through grade twelve. In the vast majority of cases, there is a course of study for each grade level. An examination of these courses usually shows much overlapping and duplication. This is not surprising since the development of the science curriculum is seldom a schoolwide project. Instead the elementary school teachers develop the elementary science program; junior high school science teachers construct the junior high school courses; and at the senior high school level, teachers take the fragmentary approach to designing courses; *i.e.*, biology, chemistry, and physics courses are often developed quite independently from each other.

This situation is quite understandable. It is often difficult for teachers working in different school buildings and at different grade levels to work together on curriculum projects. Teachers who work at a given grade level or primarily with one aspect of science often do not feel competent to judge what can or should be taught at another grade level, or in another area of science. The recent large curriculum projects of nationwide scope have each been concerned with building a course for a single year, or a small segment of the K-12 span.

A good K-12 science program will be so organized that the total program is a unit. In such a program, what is taught at a given grade level will be based on what was taught in the preceding grade and will form a foundation upon which the work of the succeeding grade will be based. A well conceived and developed K-12 program will provide an orderly growth pattern for students in science. Such a program makes possible maximum utilization of time through elimination of *needless* overlapping and repetition. This type of program allows the student to make regular and continuous progress.

It is not easy to develop a K-12 program having these characteristics. Perhaps this is one reason why no large project has been undertaken for this purpose to date. To my knowledge, only the National Science Teachers Association has taken the firm stand that the development of a real K-12 science program is a matter that deserves the highest priority among the problems in science education.

Few who read this will be in a strategic position to take concrete action toward the development of an effective K-12 program. However, every elementary teacher and teacher of science should appreciate that the emergence of K-12 programs—which are inevitable—will change his role significantly. A science teacher in the public schools can no longer afford to identify himself as a fifth-grade teacher, a biology teacher, or a general science teacher. In a K-12 program, no teacher can be an isolationist, restricted to a given grade or specialty. He must be a part of a team which, as a team, has the responsibility for providing a sound and rich experience to students for a twelve- or thirteen-year period. It seems to me that it would be wise on the part of all teachers to become as conversant as they can with the total science program.

Ralph E. Keirstead

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# SECTION 2 SOME BACKGROUND INFORMATION FOR TEACHERS

## Introduction

What is the responsibility of an elementary educator for knowing the content of science? Granted that a classroom teacher in the elementary school is not, and need not be, a science specialist, there is a responsibility as a teacher and as a citizen to develop a scientific literacy. Some knowledge of science content is essential in order to be scientifically literate. Also, although teachers can and should learn with children, it is reasonable to expect that a teacher's background is broader and deeper than that of children. To teach science, it is necessary to know some science.

How can a knowledge of science be gained? Various avenues are available if there is a willingness to learn and an interest in learning. One means of learning is to study the writing of experts in specific fields. During the past three years, issues of *Science and Children* have included articles written for elementary educators by science specialists.

The articles in this section provide some background information for teachers in the areas of biology, geology, oceanography, astronomy, and physics. Study of these articles will enrich a teacher's personal knowledge and will enhance the planning and teaching of classroom experiences. It is hoped that this section of the bulletin will prove to be a valuable resource for elementary educators, both personally and professionally.

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**BACKGROUND INFORMATION**

*Bees swarming in a tree outside NSTA headquarters in downtown Washington, D. C.*

# Arthropods

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Brooklyn College
Brooklyn, New York

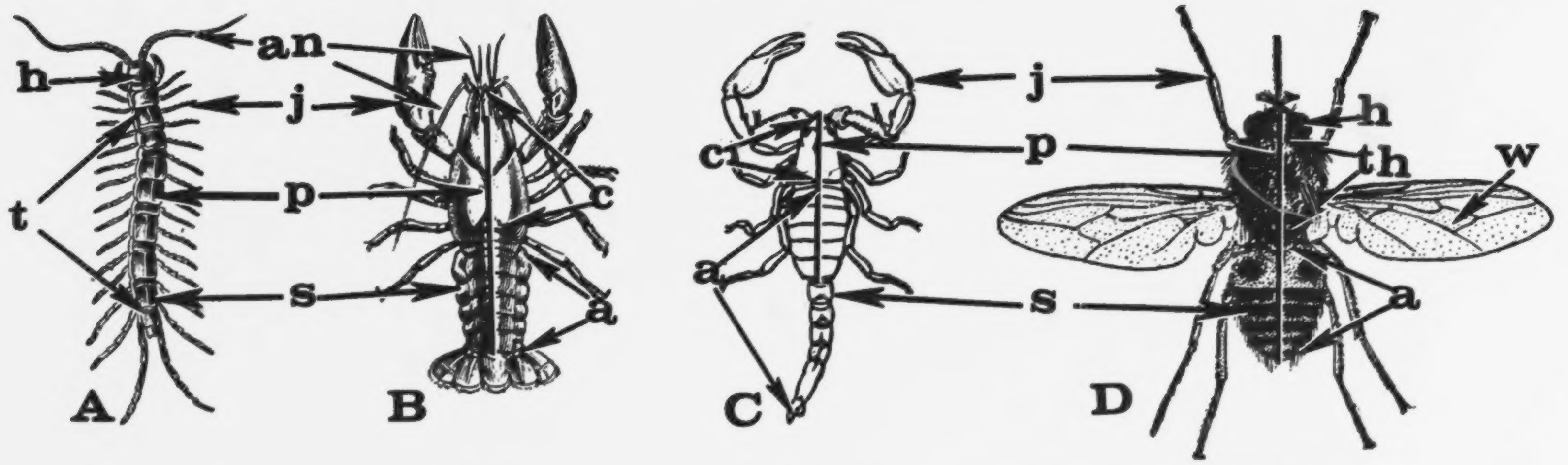
The insects and their close relatives, the millipedes, centipedes, spiders, scorpions, mites, ticks, crabs, and crayfish collectively are known as arthropods and are members of the Phylum Arthropoda. In number of species and possibly in number of individuals, the arthropods are the most common form of animal life on the earth. Wherever we wander, in the forest, along the seashore, in a field of clover, or on the front lawn, and whether we see them or not, we are in the presence of countless thousands of arthropods.

The number of species of arthropods which man has described is not known since there is no central census bureau in which the names of new forms can be recorded and tallied. Present day estimates for the total number of described animal species range from 900,000 to 1,300,000. There is some agreement among zoologists that 70 to 80 percent of all of the animals thus far described by man are arthropods.

No one ever has attempted to estimate how many individual arthropods there are in the world on any given day. There are, however, a few figures for the populations of arthropods in an acre or a square mile which are based on actual counts made on sample areas usually as small as one square foot. For example, in the top five-inch soil layer of an acre of pine forest in North Carolina, A. S. Pearse calculated there were 124 million arthropods. A similar estimate based on the two-inch soil layer of an acre of scrub oak forest in Pennsylvania gave a figure of 425 million anthropods.

Worldwide census figures for a single arthropod species do not exist, although occasionally estimates of the number of migrating individuals which pass a given point are ob-

FIGURE 1. Representative Arthropods.



CENTIPEDE CRAYFISH SCORPION TSETSE FLY

a — abdomen
an — antennae
c — cephalothorax
j — jointed
p — line of symmetry
s — segments
t — trunk
th — thorax
w — wing

tained. In the 1870's one observer in Nebraska estimated that a swarm of locusts, 100 miles long, 300 miles wide, and one-half mile high contained 124 billion individuals. In 1921, two investigators in Texas observed a migration of snout butterflies in which the swarm was estimated to number of over 34 billion individuals. These figures of 124 and 34 billion for single swarms makes man's world census figure of 2.7 billion seem quite insignificant.

## Characteristics Of Arthropods

All of the members of the Arthropoda (Gr. *arthron,* a joint; *pous,* a foot) whether water-fleas, barnacles, beetles, butterflies, or spiders have common structural features. Each is a segmented, bilaterally symmetrical animal possessing a hard exoskeleton and paired, jointed appendages. No one of these features is exclusively diagnostic, yet together they separate the arthropods from all other animals. (See Figure 1.)

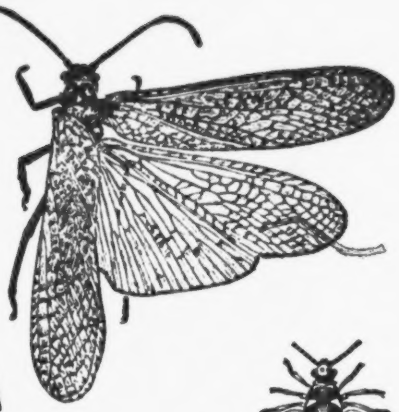
The exoskeleton, the supporting framework of the arthropod's body, merits special attention. Chemically it is made up of a very complex organic compound called chitin which is secreted by the epidermal cells in liquid form and which slowly hardens upon exposure to air. Structurally, this skeleton is made up of many hard and thick plates joined together by soft and thin articulations or joints. The resemblance to a suit of armor is clear, with the plates providing protection and support and the joints permitting mobility. Although some increase in size is possible such as that associated with feeding and egg production, any considerable increase in size can be effected only when the exoskeleton or armor is discarded and a new and larger one formed. All arthropods throw off the exoskeleton at various times during their lives by a process called molting. Before the old armor is discarded, a new, soft armor is secreted inside it by the epidermis. Some of

FIGURE 2.
Representative Insects.

A — stone fly
B — mantispid
C — butterfly
D — wasp
E — caddis fly
F — grasshopper
G — termite queen
H — biting louse
I — wasp
J — plant bug
K — mayfly
L — barklouse
M — flea
N — moth
O — earwig
P — body louse
Q — cockroach
R — dragonfly
S — ground beetle
T — scorpion fly
U — housefly
V — sandfly
W — soldier termite
X — worker termite
Y — *cicada*

TABLE I. Characteristics of the Classes of the Arthropods.

| Class | Body Regions | Legs | Antennae |
|---|---|---|---|
| MYRIAPODA (centipedes, millipedes) | Head (h) and a series of similar segments, the trunk (t). (Figure 1A) | 1 or 2 pairs on most segments | 1 pair |
| CRUSTACEA (crabs, shrimp, copepods) | Usually a cephalothorax (c) and abdomen (a). (Figure 1B) | Varying | 2 pairs |
| ARACHNIDA (scorpions, mites, ticks) | Cephalothorax and abdomen as in Figure 1C or head, thorax, and abdomen fused in one mass. | 4 pairs (Figure 1C) | None |
| INSECTA or HEXAPODA (insects) | Head (h), thorax (th), and abdomen (a) and many have 1 or 2 pairs of wings (w). (Figure 1D) | 3 pairs | 1 pair |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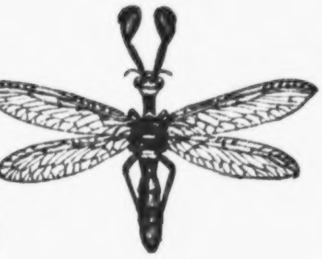
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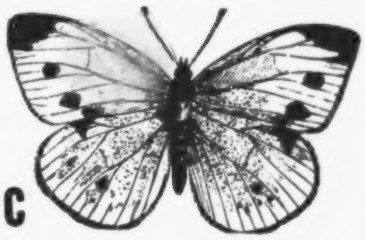
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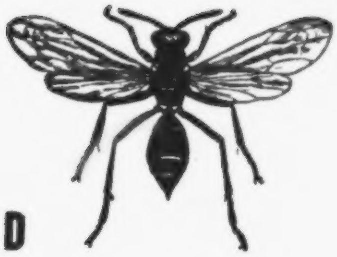
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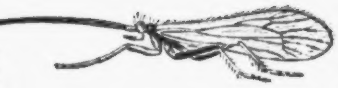
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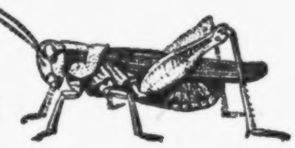
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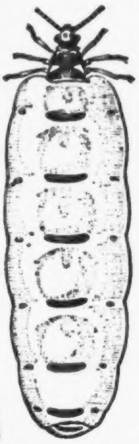
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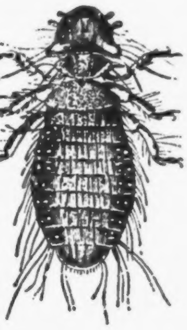
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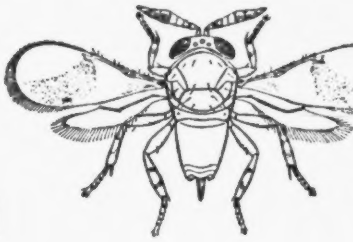
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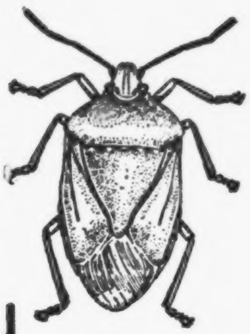
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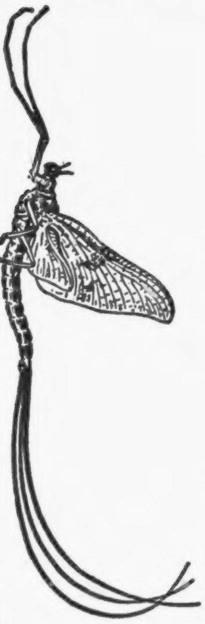
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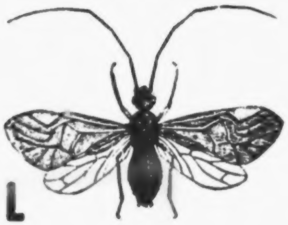
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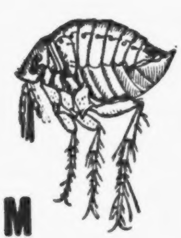
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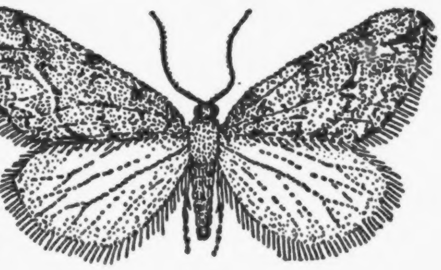
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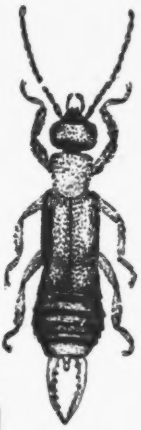
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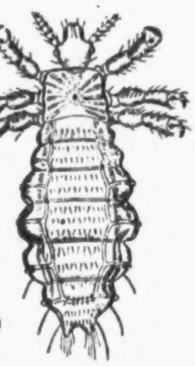
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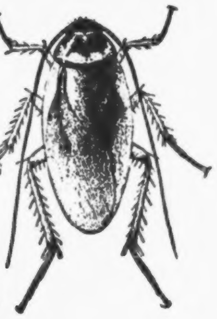
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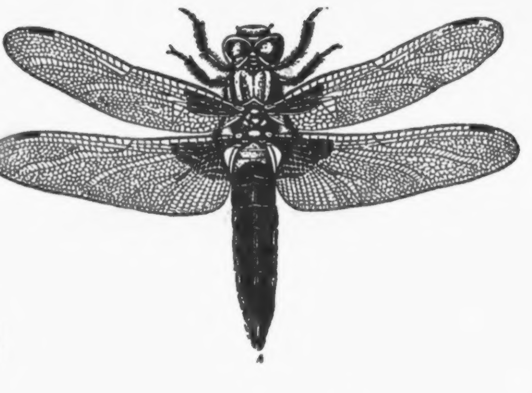
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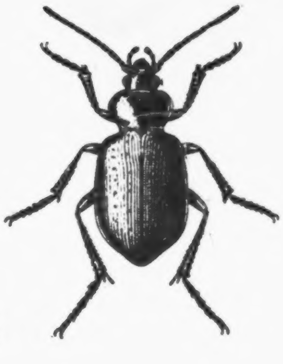
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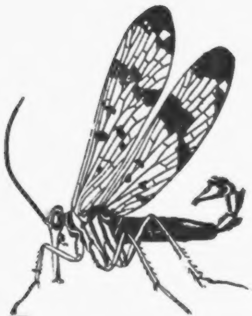
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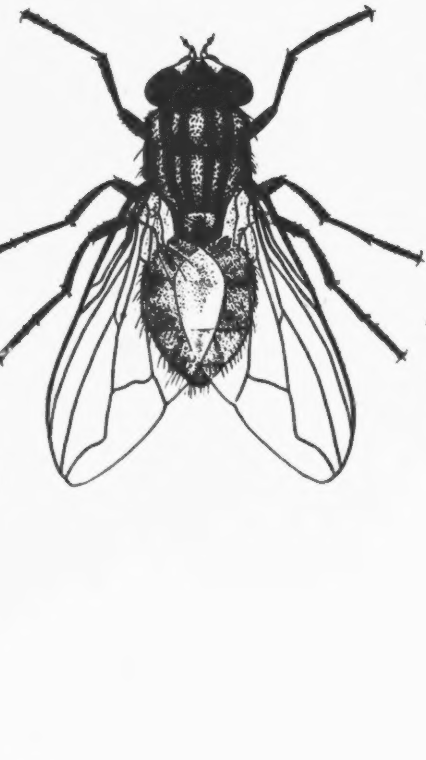
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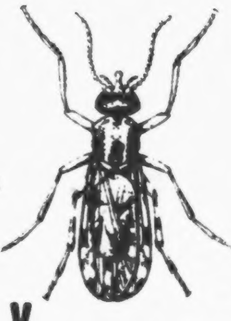
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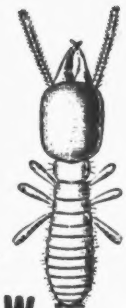
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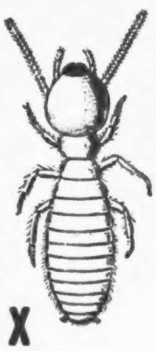
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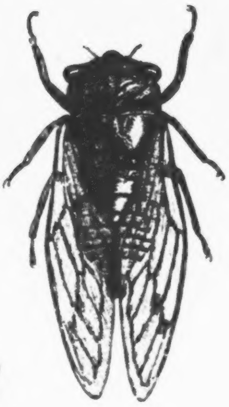
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the same epidermal cells then secrete a molting fluid which seeps out between the old and the new armor, separating one from the other. The old armor is then split open by pressure and movements from within and the arthropod frees itself from the old suit. For a period of time, the arthropod is in a soft-shelled condition during which it is extremely vulnerable to attack from enemies. During this same period, there is considerable expansion of the soft exoskeleton accomplished by swallowing air and ballooning the gut, by absorption of water into the tissues, or by other means to superficially enlarge the size of the body. By the time the new armor hardens and sets, it has been stretched sufficiently to provide space for increased growth.

In some arthropods, growth and molting cease when the adult stage is reached (insects) while in others growth and molting continue at regular periods during adult life (lobsters and crabs). It follows then that small, adult crabs and lobsters may grow and become large crabs and lobsters. However, little adult insects such as flies and beetles cannot grow to become large flies and beetles. This is a misconception which is deeply rooted in the minds of most people.

The period of time between molts is called a *stadium* and the animal during any stadium is called an *instar*. Thus, an arthropod which has hatched from the egg but has not cast its first coat of armor is a *first instar*, and the time from hatching to the first molting is the *first stadium*. Although the foregoing terms are applicable to all arthropods, their usage is more common with insects than with the other forms.

## Classification Of the Arthropods

The division of the Phylum Arthropoda into smaller groups called *Classes* is based on:

a. the manner in which the segments are massed into body regions,
b. the number and the arrangement of the pairs of jointed legs,
c. and the number of pairs of feelers or antennae on the head.

Four Classes are considered here, but there are some workers who believe that at least six groups should be given Class status. The distinguishing features of the four Classes are given in Table 1. The members of the first three Classes—the Myriapods, Crustaceans, and the Arachnids—are the close relatives of the insects and will be mentioned briefly here.

## Close Relatives of the Insects

*Class Myriapoda*—the Myriapods usually live in moist protected places such as under the bark of dead trees or under stones, boards, leaves, and other debris on the ground. The millipedes lack any poison glands and are not venomous and scarcely ever involve man in any harmful way. The centipedes, on the other hand, all have poison glands and fangs for the injection of venomous fluids. Actually, only centipedes more than 10 inches in length prove troublesome in the United States. These do not occur in any great numbers.

*Class Crustacea* — common examples in addition to those already mentioned are barnacles, sand fleas, water fleas, prawns, crayfish, lobsters, sow bugs, and pill bugs. All breathe by means of gills and live either in the aquatic environment, or as in the case of sow and pill bugs, in very moist terrestrial situations. Many of the crustaceans directly serve as a source of food for man (lobsters, crabs, shrimp) while thousands of smaller species which make up the plankton of the ocean serve as a source of food for many of the fish which are eaten by man.

A few species serve as intermediate hosts for the important worm parasites of man:

| Crustaceans | Parasite of Man |
|---|---|
| Cyclops and Diaptomus | **Diphyllobothrium latum,** the broad fish tapeworm |
| Cyclops | **Dracunculus medinensis,** the guinea worm |
| Various freshwater crabs | **Paragonimus westermani,** the lung fluke |

### TABLE II.

### Number of Described Species of Insects at the End of 1948

| Order | Common Names | Number of Species |
|---|---|---|
| Anoplura | Sucking or true lice | 250 |
| Coleoptera | Beetles, weevils | 277,000 |
| Collembola | Springtails | 2,000 |
| Corrodentia | Brooklice, barklice | 1,100 |
| Dermaptera | Earwig | 1,100 |
| Diptera | Flies, mosquitoes, gnats, sandflies, midges | 85,000 |
| Embioptera | Embiids | 150 |
| Ephemerida | Mayflies | 1,500 |
| Hemiptera | True bugs | 45,000 |
| Homoptera | Cicadas, aphids, leafhoppers, scales | 10,000 |
| Hymenoptera | Ants, bees, wasps | 103,000 |
| Isoptera | Termites, white ants | 1,700 |
| Lepidoptera | Butterflies and moths | 112,000 |
| Mallophaga | Biting or bird lice | 2,700 |
| Mecoptera | Scorpion flies | 350 |
| Neuroptera | Lacewings, antlions, dobsonflies | 4,700 |
| Odonata | Dragonflies, damselflies | 4,900 |
| Orthoptera | Grasshoppers, roaches, mantids, crickets | 22,500 |
| Plecoptera | Stone flies | 1,500 |
| Protura | Proturans | 90 |
| Siphonaptera | Fleas | 1,100 |
| Thysanoptera | Thrips | 3,200 |
| Thysanura | Bristletails, silverfish | 700 |
| Trichoptera | Caddis flies | 4,500 |
| Zoraptera | Zorapterans | 20 |

*Class Arachnida*—the Arachnids (spiders, scorpins, ticks, and mites) are air-breathing arthropods in which *at least* the first two body regions, the head and thorax, are fused to form a cephalothorax. Additionally they all have four pairs of legs—sometimes they are called octopods—and all lack antennae. Three types of individuals are found in this Class, each type makes up an *Order*. They are the scorpions (Scorpionida), the spiders (Araneida) and the mites and ticks (Acarina).

The scorpions (Figure 1C) are active at night and prey upon insects and other small forms. During the day they may be found under stones, logs, bark of dead trees, and in organic debris. Some of them have a spine and a poison gland at the tip of the abdomen. When disturbed, the scorpion may inflict a serious sting.

The spiders usually are active during the days preying upon insects and other arthropods. Many spin elaborate traps (webs) which enable them to capture prey far larger than themselves. Some have poisonous substances in their body fluids or in special glands which they use to paralyze their prey prior to sucking out the body fluids for food. Sometimes man stumbles into the web of a poisonous spider and may suffer painful consequences from the sting.

The mites and ticks are similar structurally but differ greatly in their food habits. Mites, as a group, feed upon plant juices although a very few species are parasites of man and his domesticated animals. On the other hand, all ticks are parasitic on animals during some period of their lives. Furthermore, many are transmitters of the causative agents of several human diseases such as Rocky Mountain spotted fever, tularemia, and Q fever.

## The Insects

The insects are air-breathing arthropods which have become adapted to a wide range of terrestrial habitats. If we assume that there are about 900,000 species of animals described, over 640,000 of these would be insects. In other words, the species of insects outnumber the species of all other animals combined by a ratio of 8 to 3.

Superimposed on the basic insect form of three body regions, three pairs of legs and one pair of antennae are many modifications which have aided workers to subdivide the Class *Insecta* into many Orders. An author of a recent entomological textbook considers that there are 33 Orders of insects, another author of a text of more recent vintage discusses 27 Orders and still another lists 24. Table II was taken from the *Yearbook* of the U. S. Department of Agriculture for 1952. It lists 25 Orders. Examples of 19 of these Orders may be found in Figure 2.

## Insects and Their Relation to Man

This very complex and important topic has attracted the attention of investigators for years. Volumes have been written on such facets as insects as food, as pollinators of plants, as destructors of various food crops, as agents in the treatment of disease, and as producers of silk, honey, beeswax, and many other topics. Space permits only a brief overview of the ways in which insects help or harm man either directly or indirectly. It must be borne in mind that most of the insects are neutral in that they do not appear to become involved with man in any way. Conversely, only a relatively small number of species can be regarded as good or bad.

**Insects are considered harmful to man because they:**

a. destroy or damage food and fiber crops as well as timber and timber products;

b. cause psychic disturbances such as annoyance, fear entomophobia, and entomological hallucinations;

c. produce toxic reactions by the innoculation of salivary juices (mosquitoes) or toxins via a stinging mechanism (bees and wasps);

d. are the sole transmitters of disease pathogens of many human diseases such as:

| Disease | Transmitter |
|---|---|
| Dengue | Mosquito |
| Yellow fever | Mosquito |
| Typhus fever | Lice |
| Malaria | Mosquito |
| Sleeping sickness | Tsetse fly |
| Filariasis | Mosquito |
| Bubonic plague | Flea |

e. infest the surface of the body (lice and mites) or invade the body cavities (fly maggots) and cause discomfort; and

f. are a source of substances (allergens) which result in allergic responses. In United States during the period 1950-59, the stings of hymenopterous insects killed 229 persons. All of these can be considered allergic deaths.

**Insects are considered helpful to man because they:**

a. pollinate the flowers of food plants, especially many of the common fruit and vegetable crops;

b. cause the destruction of harmful insects, *i.e.,* the cottony-cushion scale of California by the vedalia beetle introduced from Australia;

c. cause the destruction of harmful plants such as the prickly pear (cactus) in Australia by the moth, *Cactoblastis cactorum,* imported from the Americas;

d. provide such commercial items as honey, beeswax, cochineal silk, and pigments used for the ink employed in British and American currency;

e. can serve directly as a source of food as described by Bodenheimer in his text *Insects as Human Food* (W. Junk Publishers, The Hague, 1951);

f. and may be employed to hasten the healing of wounds (maggot therapy).

young caterpillar

beginning the change

changing into c

**EMILY STOBBE**

Monarch Butterfly
Research Associate
University of Toronto
Toronto, Canada

# Tagging the Butterfly

CHILDREN are fascinated by the emergence of a butterfly from its chrysalis and the transformation of a caterpillar to pupal stage. A complete metamorphosis, taking only one month, can be observed in the classroom by raising monarch butterflies.

The pin-point cream eggs and larvae of the *Danaus plexippus* can be collected from a milkweed patch. The caterpillars have voracious appetites for the milkweed leaves and need a constant supply. A suitable container for classroom display can be made either from a shoebox with a plastic see-through top or a fine wire cylinder set in a filmstrip can with the cover for the top. Here, the complete changes in the cycle are visible at all times.

However, the appearance of the adult butterfly need not be the end of the project. Fred A. Urquhart of the University of Toronto, Canada, has been directing an international migratory study on the monarch for the past 13 years to discover "where butterflies go." So far, butterflies have been tagged by persons in Canada, the United States, and Australia. There is a need for more volunteers who will raise a minimum of 25 monarch caterpillars and tag the adults.

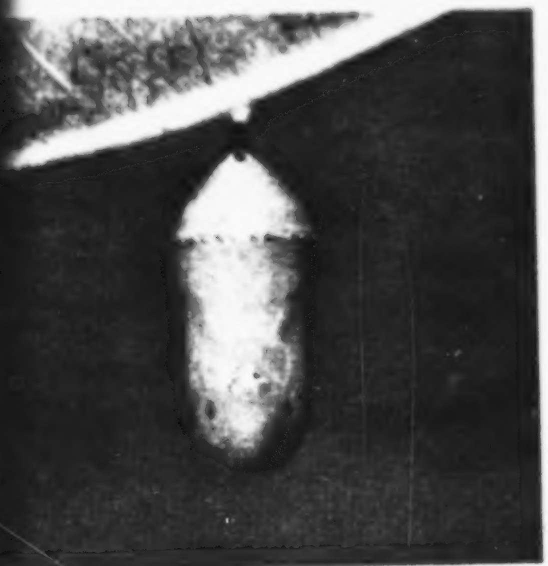
A ½ x ¼-inch self-adhesive sticker is used for the tagging. It does not interfere with the flight of the butterfly in any way. To attach the tag, rub a small front section (discal cell) of one wing lightly between thumb and finger to scrape off the "dust" (microscopic scales) and leave a transparent area. Then fold the tag over and press firmly at this spot. It instructs anyone finding one of these specimens to send it to the address on the label, noting the time and place of capture. Only a few out of thousands of butterflies are captured, but this ratio will rise with the help of more taggers. In a yearly newsletter about the study, Dr. Urquhart reports on the locations and dates of latest captured specimens and other "butterfly news."

Teachers interested in this study project should contact: Dr. Fred A. Urquhart, Zoology Department, University of Toronto, Toronto, Canada. A fee of $3 is asked by Dr. Urquhart to cover the cost of tags and the yearly newsletter.

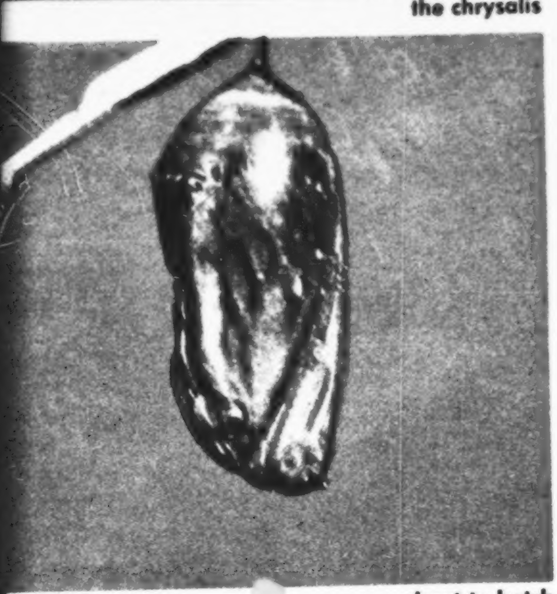
## Background Information

The migration of the monarch is not unique in the *Lepidoptera* world, but its flights have been of such

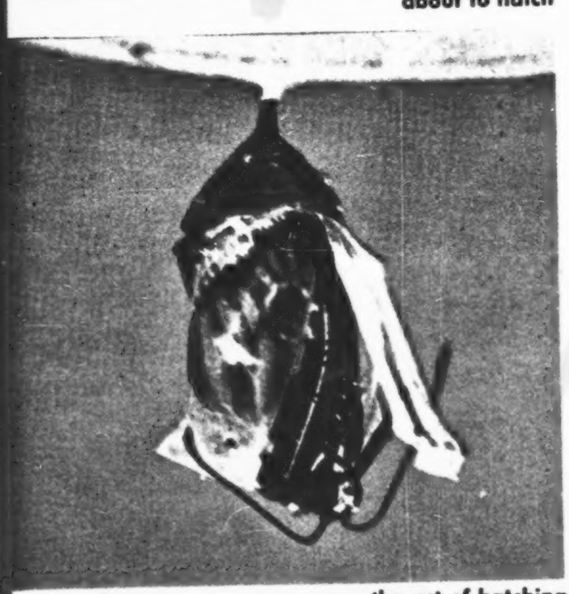
**The color photographs were made available to *S&C* through the courtesy and cooperation of Encyclopaedia Britannica Films, Inc., and the National Wildlife Federation. They are from the EBF educational film, "Monarch Butterfly Story," and appeared in *National Wildlife*, 1:8, August/September 1963.**



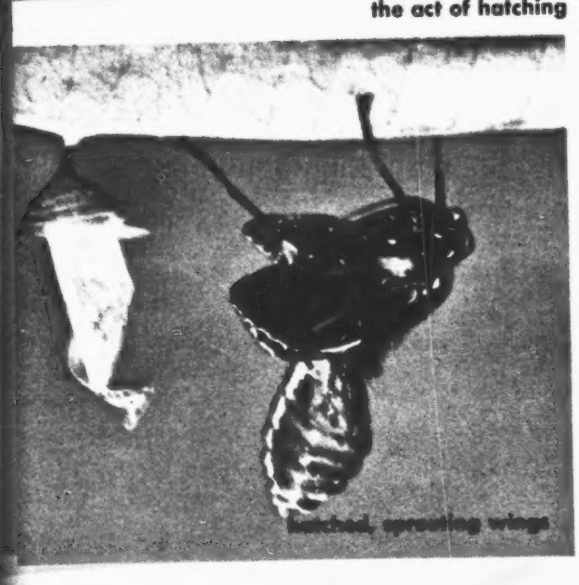
the chrysalis



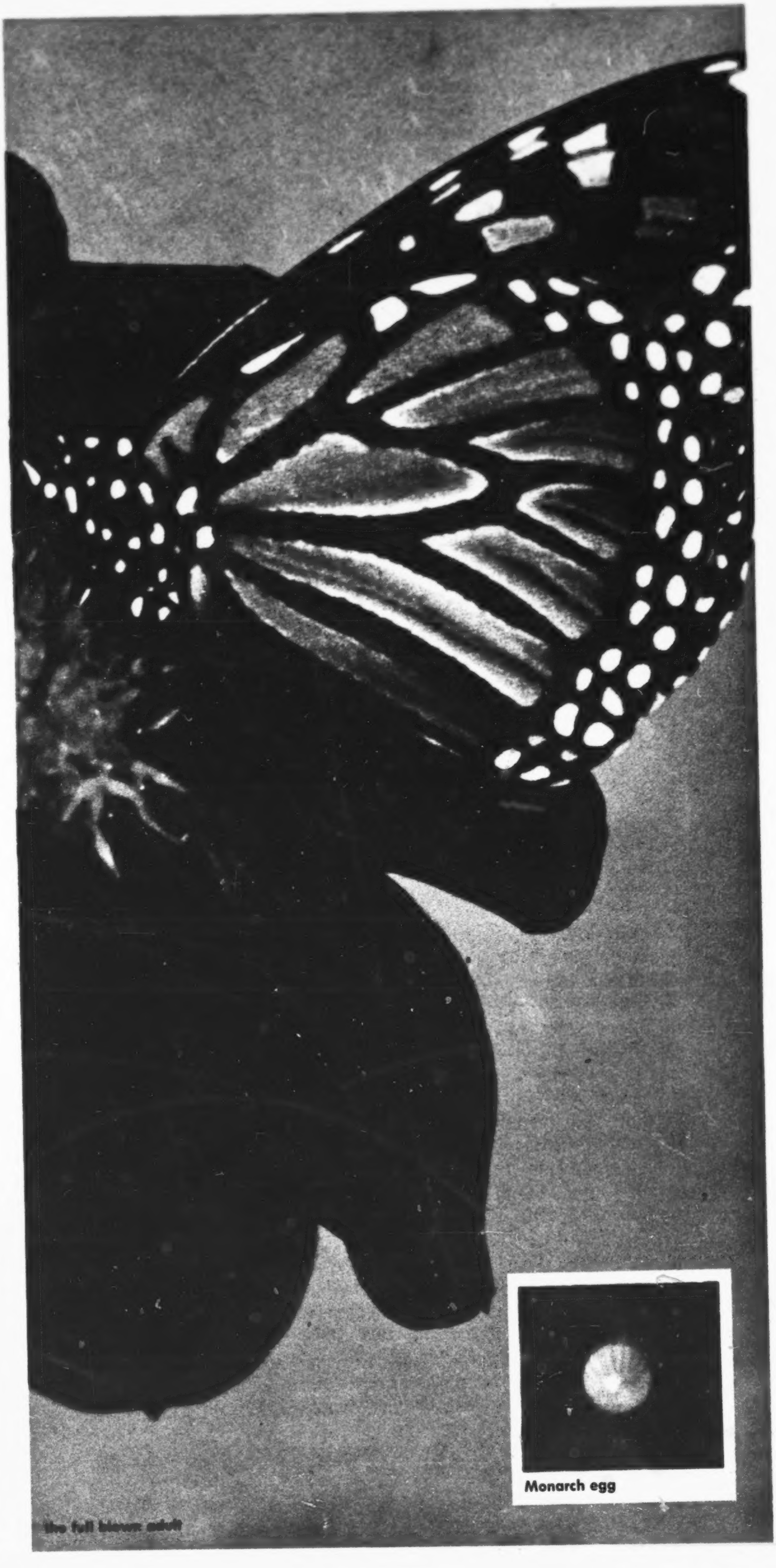
about to hatch



the act of hatching



hatched, sprouting wings



the full blown adult

Monarch egg

great distance that scientists have been intrigued for decades. With a wingspan of three to four inches, this insect is believed to cross oceans. The longest recorded flight was from eastern Canada to Mexico, almost 2000 miles. The chilly fall air sends the monarchs to warmer climates—those from New York overwinter in Florida while those leaving Wisconsin go to Texas. The Pacific Northwest group migrates to the California coast where they unerringly choose the same trees for roosting as were chosen by the generations before them.

With the advent of spring or the end of cold weather, the monarchs head north and/or east. Females lay up to 400 eggs, one at a time, on milkweed leaves—the sole diet of monarch larvae. Some females fly a short distance before ovipositing, but others may travel hundreds of miles.

The black, yellow, and white-striped caterpillars that hatch in a few days or a week spend their two weeks of life devouring milkweed leaves, moulting, and preparing for the change to chrysalis. The caterpillar requires only about 12 to 14 days to transform into a butterfly.

*A tagged monarch—what are the chances of capture and return to the University of Toronto?*

# RECENT BOOKS ABOUT MONARCH BUTTERFLIES

**HILARY DEASON**
Editor
**Science Books,** AAAS
Washington, D. C.

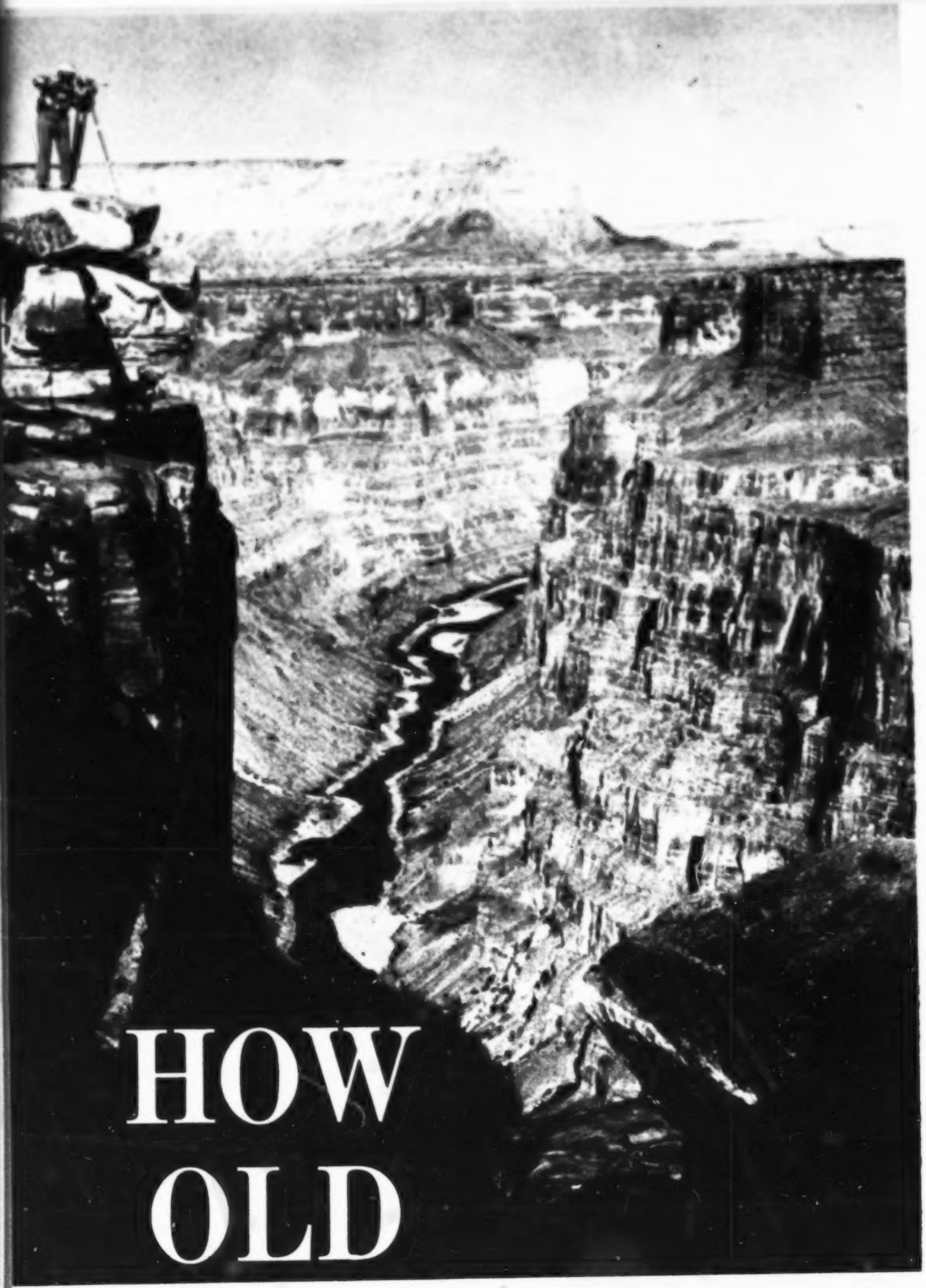
**Monarch Butterflies.** Alice L. Hopf. (Illustrated by Peter Burchard.) 136p. $3.75. Thomas Y. Crowell Company, 201 Park Ave. South, New York City 10003. 1965.

The initial reaction of many teachers and librarians to the publication of another children's book on butterflies might well be that the subject has been adequately covered in books previously published for all age levels. However, in the spirit of modern science teaching which endeavors to involve the young reader in the processes of science, Miss Hopf's book is a very welcome addition to children's literature. She summarizes the life history of the monarch butterfly, describes marking techniques that have been used to study its migration, and tells young readers how they can collect eggs and caterpillars and care for them through to the adult stage.

The descriptions of technique, procedures, equipment and the instructions for photographing insects are good. The sparse black-and-white illustrations are satisfactory, but the book would have been enhanced by a few color illustrations and more drawings or diagrams on technique. Occasionally the author "writes down" to her readers and uses anthropomorphisms, e.g. "bringing up baby," that should be avoided in scientific writing for youngsters. Additional references and a list of firms that sell insect-collecting supplies are included. This book will be useful in school and public libraries and as a home acquisition for children in the middle and upper grades, including some junior high students.

**The Travels of Monarch X.** Ross E. Hutchins. (Illustrated by Jerome P. Connolly.) 64p. $2.95. Rand McNally and Company, 8255 Central Park Ave., Skokie, Ill. 60076. 1966.

A well-known professional entomologist and the author of many children's books has combined his talents with those of a skillful museum artist to discuss the migration of the monarch butterfly. The *Preface* informs the reader that, based on the investigations of Fred Urquhart of the University of Toronto, the story concerns the migration of one typical, marked monarch butterfly which was released on September 18, 1957 and captured on January 25, 1958 in Mexico. The two following pages, *Scientific Notes*, gives a resumé of the life history, describe methods of migration studies, and offer some observations on "navigation" of butterflies. Then, in larger type and in simpler language, the story begins with an egg laid on a milkweed plant, and continues with the hatching, growth of the caterpillar, its transformation into a chrysalis, the final emergence of the adult, and then its capture and marking. Then begins the migration story ending with capture, removal of the tag, release of the butterfly and the mailing of a report on recovery to the Royal Ontario Museum. The color illustrations that accompany the exposition of a unit idea on each page are examples of ideal layout for children's science books. A note at the end invites the interested reader to inquire of Dr. Urquhart concerning collaboration in his migration studies. This book is appropriate for all elementary school students— the younger ones will need some guidance from parents or teachers, but older ones can enjoy it by themselves.



# HOW OLD IS OLD?

**ERLING DORF**
Professor of Geology
Princeton University
Princeton, New Jersey

Nowadays nearly everyone realizes that the earth is very old and that many events of the prehistoric past took place a long time ago. But the question invariably arises as to how old "very old" really is in the geologic sense. Students also want to know whether or not there are methods whereby we can reliably calculate in actual years how long ago certain geologic events occurred.

It is perhaps best at the outset to think of geologic time in relative terms and then later to proceed to a consideration of time in its absolute terms.

Relative time may be considered in relation to a certain event in earth history having happened before or after some other event. This is analogous to knowing that the American Revolution preceded the French Revolution. Accurate knowledge of this sequence of events is established by both written records and calendars. In the record of the rocks, however, the relative sequence of geologic events must first be determined by what is known as *superposition.* As shown in Figure 1, in any undisturbed sequence of stratified rocks the topmost layers are always the youngest and the underlying layers are progressively older and older. In such a sequence of stratified rocks it has further been observed that the fossils of each successive rock unit are recognizably different from those in the units above and below.

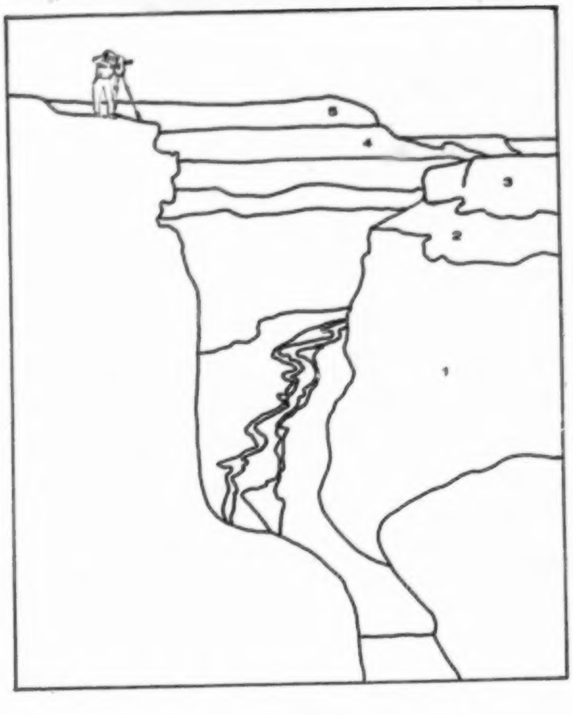


*FIGURE 1. Relative ages of successive rock units, as determined by superposition and by distinctive fossils. (5) Youngest rock unit. (4) Next to youngest rock unit. (3) Older rock unit. (2) Still older rocks. (1) Oldest rock unit.*

From the combination of superposition and characteristic fossils, geologists have constructed a *Geologic Time Table.* (See Chart.) The time units, known as Eras, Periods, and Epochs, are strictly relative to each other and were conceived without any knowledge of their absolute values in terms of actual years.

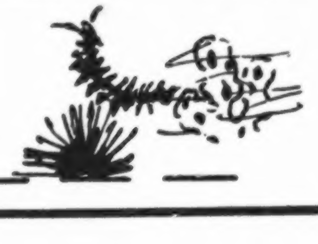
Attempts to determine absolute dates in earth history involve several different scientific methods. In 1883 Lord Kelvin of England calculated on the basis of an estimated rate of cooling of a once-molten earth that not more than 40 million years had elapsed since the molten earth had solidified in the Early Precambrian. Darwin took issue with this figure, arguing that at least 80 million years were required to account for the amount of evolution which had taken place among plants and animals since the beginning of the Cambrian Period. Both of these estimates, we now believe, were based on very indefinite, and in part erroneous, concepts.

Another way to calculate earth history has been based on the time required for the deposition of sedimentary rocks. At an estimated rate of one foot of sediment laid down in about 200 years, the total of more than 360,000 feet of strata down to the base of the Cambrian (see Chart) was calculated in the late 19th century by one geologist to have been deposited in about 28 million years and by another in about 48 million years.

By the beginning of the 20th century still another method was

## THE GEOLOGIC TIME TABLE

(Modified after the United States Geological Survey)

| ERA | PERIOD | EPOCH | MAJOR FOSSIL GROUPS | BEGINNING OF TIME UNIT |
|---|---|---|---|---|
| CENOZOIC | QUATERNARY | Recent | Chiefly Mammals; Flowering Plants; Pelecypods, Gastropods, and Foraminifera. | |
| | | Pleistocene | | 1,000,000 |
| | TERTIARY | Pliocene | | 10,000,000 |
| | | Miocene | | 25,000,000 |
| | | Oligocene | | 40,000,000 |
| | | Eocene | | 60,000,000 |
| | | Paleocene | | 70,000,000 |
| MESOZOIC | CRETACEOUS | | Chiefly Reptiles; Cycads, Conifers, and Ginkgoes; Ammonites and Belemnites. | 125,000,000 |
| | JURASSIC | | | 150,000,000 |
| | TRIASSIC | | | 180,000,000 |
| PALEOZOIC | PERMIAN | | Chiefly Amphibians; Ferns, Seed-Ferns, Scale-Trees, Calamites and Cordaites; Large Insects, Productids, Fusulines, Crinoids, Blastoids. | 205,000,000 |
| | PENNSYLVANIAN | | | ? ? |
| | MISSISSIPPIAN | | | 255,000,000 |
| | DEVONIAN | | | 315,000,000 |
| | SILURIAN | | Chiefly Primitive Fishes; Simplest Land Plants; Trilobites, Corals, Graptolites, and Cystoids. | 350,000,000 |
| | ORDOVICIAN | | | 430,000,000 |
| | CAMBRIAN | | | 510,000,000 |
| PRECAMBRIAN | | |  Chiefly Sea Weeds and Fungi; Few Soft-Bodied Aquatic Invertebrates. | 3,000,000,000 + |
| ? | | ? | | |

tried. This was based on the supposition that the oceans were originally composed of fresh water and that their present content of dissolved salts has slowly been washed into them from the lands at a determinable rate. Since the salts of the oceans are mainly rock salt (sodium chloride), the element sodium was used in these calculations. On the basis of an estimate of about 160 million tons of sodium washed into the oceans each year compared to a total of about 14 billion tons at present, the time since the origin of the fresh-water oceans was determined as about 90 to 100 million years. Later calculations, based on better data, have revised these figures upward to more than 500 million years.

During the last few decades there has been developed a new method of time measurement which is generally regarded as much more reliable than any previous attempts. This is based on *radioactivity,* the process whereby certain rock-forming minerals contain elements whose nuclei spontaneously decay, resulting in the formation of new elements as stable end products. Since the annual rate of this spontaneous decay could be determined, the actual number of years since the radioactive mineral was formed could readily be calculated.

Let us illustrate by means of the radioactive decay of uranium-238, well known because of its use in atomic bombs. In the spontaneous decay of uranium-238 atoms (see Figure 2), there are emissions of alpha particles and beta particles. As a result of these minute discharges, the uranium-238 passes through several very unstable stages and finally changes to the stable element lead-206. The rate of uranium-238 decay has been shown to be constant, regardless of the surrounding physical or chemical conditions. This rate of radioactive decay is usually expressed by the term *half-life; i.e.,* the time required for half the original quantity to decay. The half-life of uranium-238 is about 4.5 million years, which means that one original ounce of uranium-238 will be reduced to half an ounce of uranium-238 and half an ounce of lead-206 in 4.5 million years. With this knowledge as a background, careful analyses and calculations make is possible to find the age in millions of years of any mineral containing uranium-238 by determining the ratio of the lead to the uranium. Among other elements the following ratios can also be used in absolute age determinations: thorium-lead, rubidium-strontium, and potassium-argon. For ages up to about 45,000 years the amount of carbon-14 in carbon-containing fossils has also yielded absolute ages.

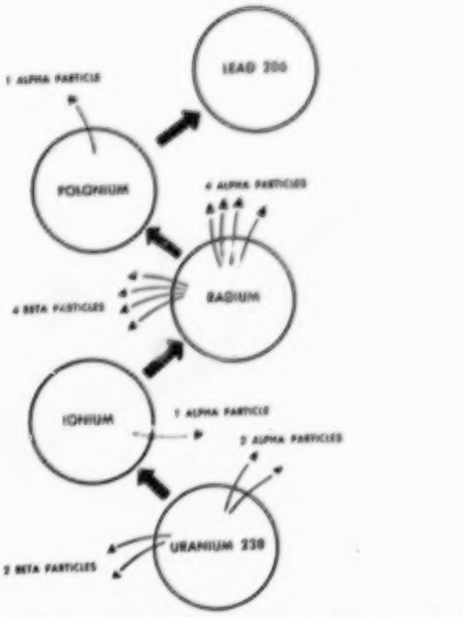
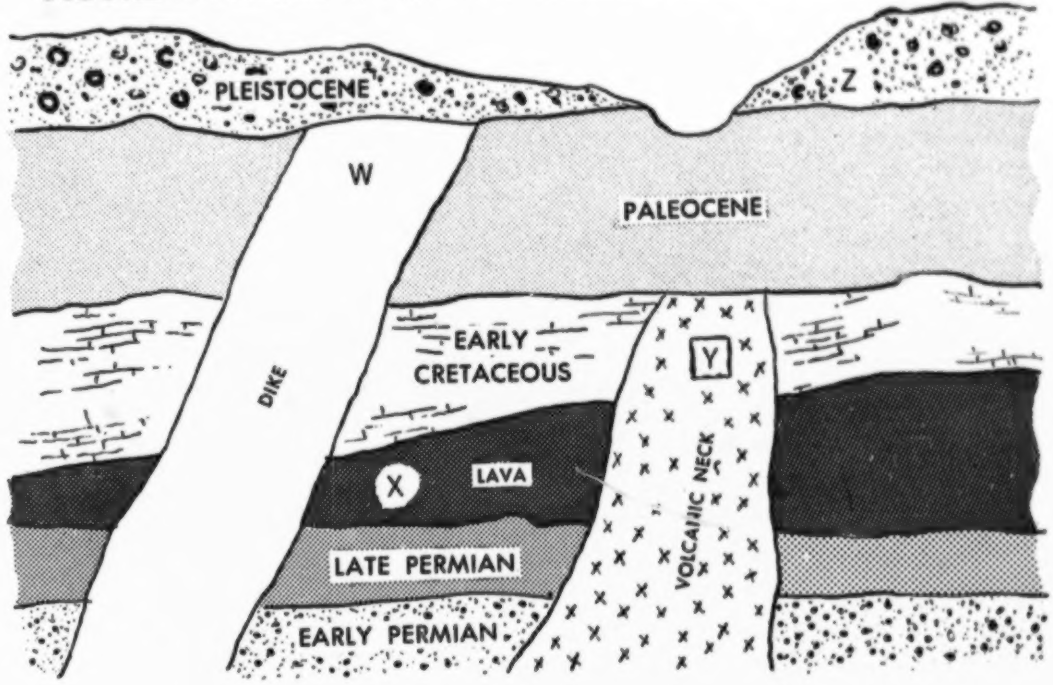


*FIGURE 2. Spontaneous decay of uranium-238 atom by emission of alpha and beta particles, showing unstable intermediate stages and the stable end product, lead-206.*

*FIGURE 3. Relations of different radioactive specimens to geologic ages.*



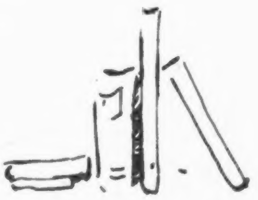
After such age determinations have been made, there still remains the task of finding out the geologic period or epoch to which the radioactive specimen belongs. In Figure 3, for example, specimen *W* could be referred to only as post-Paleocene pre-Pleistocene, specimen *X* could be dated as post-Permian pre-Cretaceous, specimen *Y* as probably Late Cretaceous, and specimen *Z* as definitely Pleistocene.

Analyses of a great many radioactive specimens which have been closely dated geologically have now made it possible to attach dates in actual years to the beginnings of nearly all of the Geologic Periods and Epochs, as shown in the last column of the Chart. So our geologic calendar must now be thought of in terms of millions, hundreds of millions, and even billions of years.

## References

1. Arthur Holmes. *The Age of the Earth.* Thomas Nelson and Sons, 18 East 41st St., New York 17, N. Y. 1937.
2. Adolph Knopf. "Measuring Geologic Time." *Scientific Monthly.* 85:225-236. May 1957.
3. L. D. and Judson S. Leet. *Physical Geology.* Second Edition. Prentice-Hall, Inc., Englewood Cliffs, N. J. 1958. Chapter 8.
4. F. E. Zeuner. *Dating the Past: An Introduction to Geochronology.* Methuen and Company, Ltd., 36 Essex St., Strand, London, England. 1952.

# Recognizing Rocks And Minerals



**RICHARD M. PEARL**
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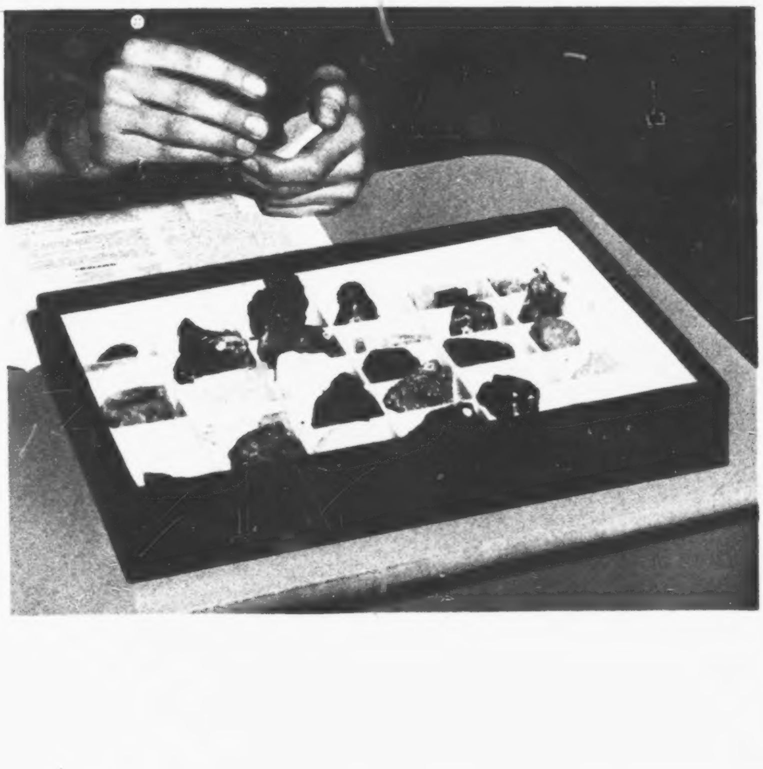
Colorado College
Colorado Springs, Colorado

Identifying minerals and rocks can be almost as easy or as difficult as you are willing to make it.

In a simplified version, such identification need not be at all hard or complicated. It can serve the purpose of the elementary school teacher quite satisfactorily and can be put into effect immediately. This method is presented here. Carried to an extreme, the same identifications can become among the more complex of natural science techniques. If identifying all the multifarious products of the mineral kingdom were as easy to learn as, say, running an elevator, no self-respecting scientist would care to become a professional mineralogist or petrographer.

Unlike butterflies, birds, or even postage stamps, minerals cannot be identified by a simple comparison with the pictures in a book. As the author of one of the standard field guides on the subject, I must admit that the colored photos in the book serve little purpose except to encourage sales.

The reason for this difference is that the objects other than minerals that are mentioned are classified on the basis of their appearance; and when they look different, they are almost certain to bear a different name and be found under a different heading. Minerals, however, are classified according to their *chemical composition* (which is not determined at sight) and their *crystallization* (for which you may have some good clues in the geometry of the specimen). Rocks, in turn, are named according to their *mineral content* and their *texture*. Color is sometimes useful in aiding us to recognize minerals and rocks, but it is often so variable as to be more of a puzzle than a feature one can depend on.



*A small collection of the most common minerals is a must when studying specimen identification. Three of the most often found specimens are shown at the above right (top to bottom); feldspar, calcite, and quartz.*

*Identification charts, specimen samples, and the help of a professional give the student a clearer picture of earth science.*

Hence, to know that there are perhaps 1600 to 2000 different mineral specimens, depending on how they are classified, and many varieties of some of these, sounds formidable indeed. Nearly a thousand rock names have also been proposed.

### Minerals

But, here is the real secret of mineral identification: only a handful of names make up almost all the specimens that your students are apt to find and bring in for identification. Similarly, only a very few of the varieties of even the most diversified mineral (even of calcite, which has been described in more than 300 different forms) will come to hand. If you learn to recognize these relatively few minerals and make a few easy tests, the problem reduces itself to manageable proportions.

With this confidence gained, new minerals can be added from time to time, but each new mineral is less and less common than the ones previously acquired. I have often told teachers that if they can recognize calcite, feldspar, and quartz they will be able to identify nine out of ten specimens brought into the classroom. This is a good percentage; beyond that limit, even professional mineralogists would usually want to make laboratory tests to be sure of the rest.

Now to start. One must have on hand a box of named specimens—20 is enough—each an inch square or larger, bought for $5 or less from a recommended dealer. Some souvenir boxes that are sold look impressive, but the names are not correct; information about uses, and occurrence, can be looked up and is not an essential part of the collection—but the correct names are.

The next step is to make comparisons often, every hour on the hour, until the samples become familiar to you.

Each time you look at a mineral, known or unknown, "heft" it for density or specific gravity. This useful distinction between typical minerals (either metallic looking or nonmetallic) and those that are noticeably lighter or heavier than typical, will shortly become second nature to you. Use pyrite (metallic) and quartz (nonmetallic) as standards. The specimens should be about the same size for the "heft" test.

The only mineral at all common that will respond vigorously to a magnet is black magnetite. Compare this with any weaker magnetic mineral and you will not be confused.

The only chemical test you will make, unless you are a teacher of chemistry and have reagents handy, is the "fizz" test for carbonates. Nearly all specimens that "fizz" will be calcite (the mineral), or limestone, or marble (the rock). A little weak acid, kept in a stoppered bottle bought for a few cents at the drug store, should be safe enough for use in the classroom. Salt (halite), of course tastes salty, but practice sanitary "rockhounding" and do not allow the students to lick specimens.

*These amateur "rock hounds" enjoy a day of specimen hunting in the mountains.*

Hematite and limonite will give their characteristic colors when rubbed on a streak plate, which is merely a piece of unglazed porcelain. A broken china dish or cup will do as well as commercially obtained streak plates.

Hardness is an important property of minerals. It is determined by scratching the specimen on a piece of glass or knife blade, or trying to scratch it with a pin or knife. The Mohs scale of relative hardness is given in every book on the subject.

With hardness, streak, acid test, magnetism, luster, and specific gravity as keys, the common (meaning abundant) minerals will soon be under control. As mineral identification becomes easier, you will feel encouraged to learn a larger number of kinds. If the specimen does not match the standard samples at all, it may be rare and may warrant being looked at by a local geologist or active member of a mineral club. I say "I don't know" every day in the week, and you may have to also.

### Rocks

As to rocks, the keys are: identify the constituent minerals and look carefully at the texture (the arrangement of the minerals). You will do well to get familiar with the interlocking texture of igneous rocks, the granular or uniform texture of sedimentary rocks, and the wavy texture of metamorphic rocks. These are not absolutely dependable criteria but are nevertheless useful enough to be worth looking for. Natural glass (obsidian) and the carbonates (which "fizz") offer a special but easy approach.

Then compare, compare, compare. When you and the class can recognize all the samples, order a larger standard collection. No two rocks are alike, but the common ones in any locale will appear again and again.

# Sources of Free or Inexpensive Conservation Materials*

**American Forest Products Industries, Inc.,** Madison, Wisconsin. *Conservation Pledge, Suggestions for Integrating Forestry into the Curriculum, Forest and Wildlife, How a Tree Grows, Smokey the Bear Fire Protection, What We Get from Trees, The True Story of Smokey the Bear.*

**The Conservation Education Association,** Wilson Clark, Eastern Montana College, Billings, Montana. *Conservacation Quickie.* (Single copies free; $3 per 100 copies.)

**The Conservation Foundation,** 30 East 40th Street, New York, New York 10016. *Bulletin on Conservation Education.*

**Garden Club of America,** 511 Lake Avenue, Greenwich, Connecticut 06833. *Packet of Materials* (50 cents).

**Interstate Printers and Publishers, Inc.,** Danville, Illinois 61834. *This Is Our Soil* (50 cents).

**National Audubon Society,** 1130 Fifth Avenue, New York, New York 10028. Write for free order folder listing *Audubon Nature Bulletins and Audubon Nature Charts,* titles, and prices.

**National Wildlife Federation,** 1412 Sixteenth Street, N.W., Washington, D. C. 20036. *Raindrops and Muddy Rivers* (25 cents); *Plants and Animals Live Together, Nature's Bank—The Soil.*

**Shorewood Publishers, Inc.,** 724 Fifth Avenue, New York, New York 10019. *Sportsman's Map of U. S. Wildlife* ($2).

**Soil Conservation Society of America,** 7515 N. E. Ankeny Road, Ankeny, Iowa. *Down the River* (10 cents), *Help Keep Our Land Beautiful* (20 cents), *The Story of Land* (20 cents), *Making a Home for Wildlife on the Lands* (20 cents).

**Sport Fishing Institute,** Bond Building, Washington, D. C. 20005. *Conservation Chart* ($1).

**United States Department of Agriculture,** Soil Conservation Service, Washington, D. C. *Teaching Conservation in the Elementary School, The Soil That Went to Town, The Teaching of Soil and Water Conservation.*

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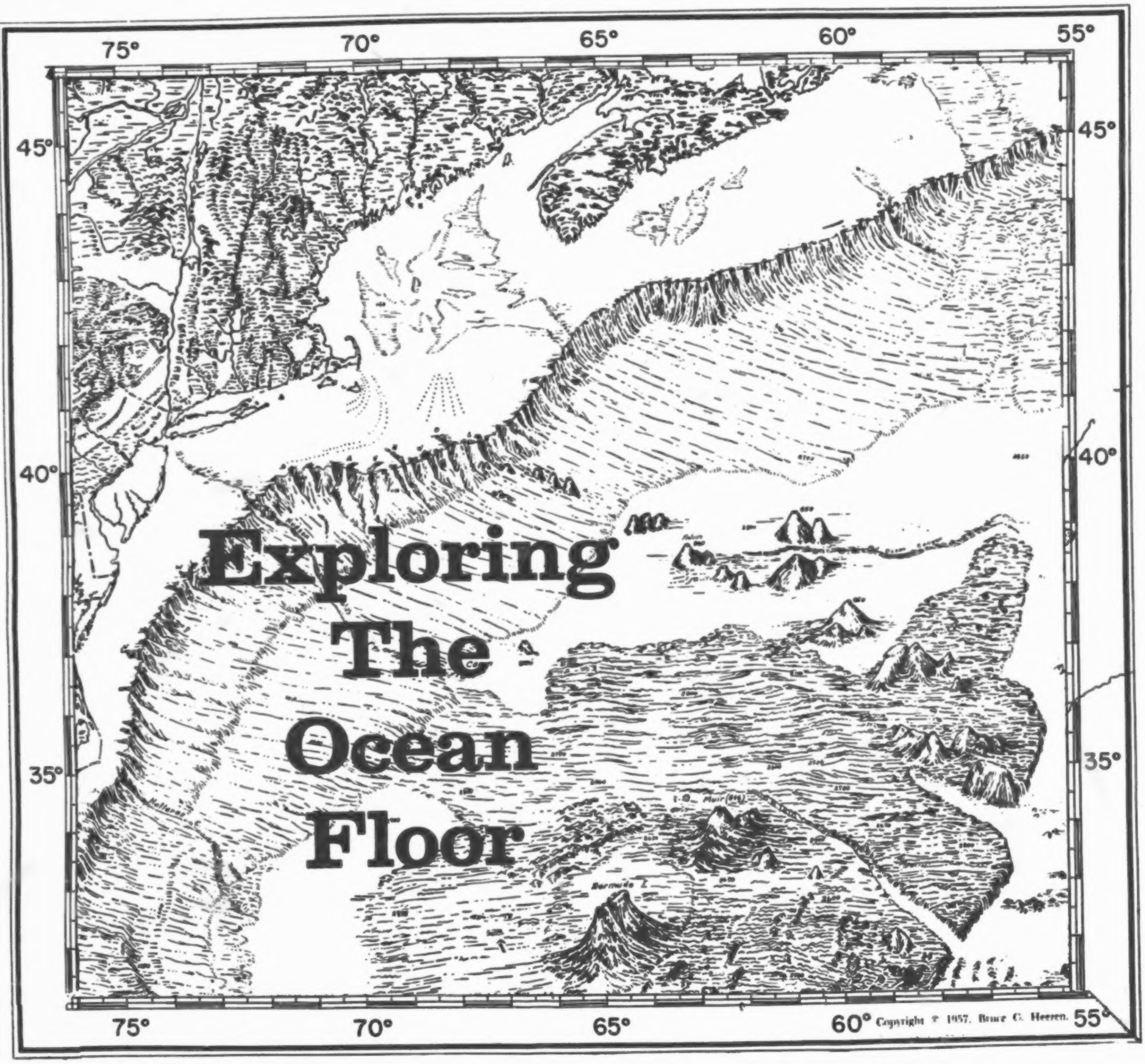
* All items listed here are free of any charge unless otherwise noted.

# Exploring The Ocean Floor



Copyright © 1957, Bruce C. Heezen.

*This map was compiled from many fathograms taken over the years. It shows the ocean bottom in the North Atlantic near New York. Vast mountain ranges, deep gorges, and broad, flat plains make up the undersea landscape.*

**MARCUS G. LANGSETH**

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A study of natural science usually begins with observations that we can make with our five senses. But there are many places in the universe where we cannot depend upon these senses; for example, the interior of the earth, outer space, and the microscopic world. Here we must rely upon such instruments as the telescope, the microscope, the satellite, and the earthquake seismograph to extend our senses, if we hope to do more than guess about these unseen worlds.

Similarly, the ocean floor lies hidden from our view below a vast layer of water covering almost three-quarters of the earth's surface. In many places, this water is three or more miles deep. Such depths present formidable obstacles to the explorer of the ocean bottom. The pressure of the water at such depths is enormous; for example, at a depth of 20,000 feet the pressure on a box a foot square could be 3840 tons. Very long wires and powerful hauling devices are needed to lower instruments or men to the ocean bottom from a research ship. The salty water of the ocean is a corrosive fluid which attacks many of the metals from which the instruments are made and shortens their span of usefulness. Furthermore, below 3000 feet none of

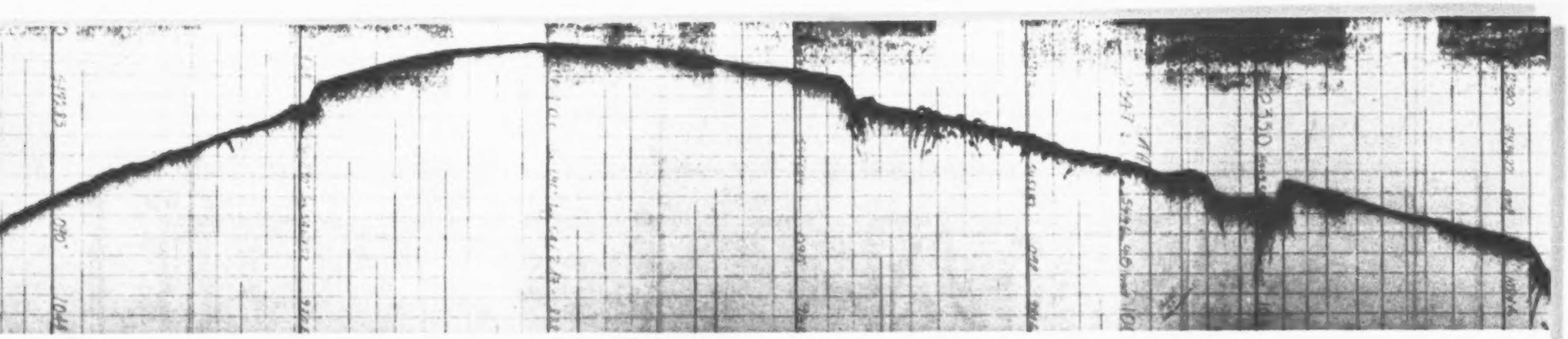


FIGURE 1.

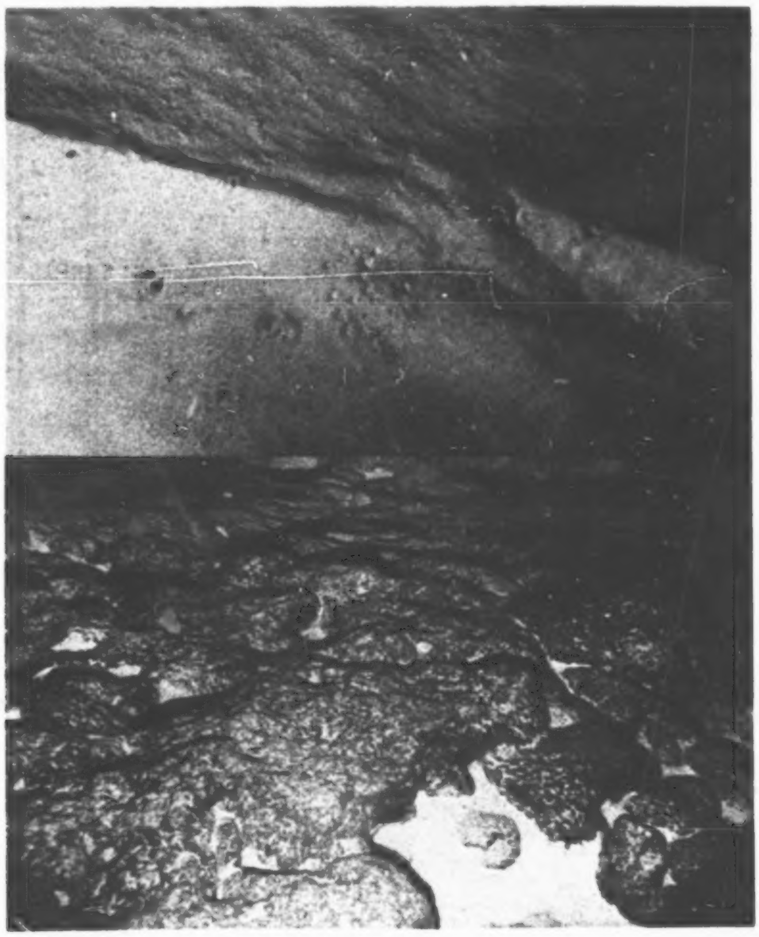


FIGURE 2.

the sun's light penetrates even at high noon, leaving the deep open floor a dark and cold world. So formidable did this world seem to early ocean scientists that they believed it to be a barren and lifeless deep covered with sediments that had fallen like snow through the water above during the eons of time.

To penetrate this water barrier, many simple, yet ingenious devices have been made. The development of these instruments has been the key to unlock the secrets which lie at the bottom of the ocean. It is also important to understand these instruments' limitations, for we still know only a small fraction of the secrets hidden in the ocean deeps. I shall discuss three important oceanographic instruments and the way they are used to help us get a picture of the ocean floor.

To determine the shape of the ocean floor, we must find the depth of a sufficient number of well-located spots, so that when they are plotted on a chart they define the contours of the bottom. In the late nineteenth century, such depth determinations (soundings) were made with thin piano wire, the end of which was attached to a heavy weight. This weight was lowered from a stationary ship until it touched the bottom. These soundings were first made by hand and later by winding machines or winches. It was a long and arduous task, lowering miles of wire to the bottom and then recovering it. Understandably, such soundings were made at widely separated stations; but from the hard work of these early explorers, we learned that the oceans are principally underlain with great depressions in the earth's surface miles deep and of great areal extent. They also discovered that even in the center of the oceans the water can be shallow, indicating submerged peaks.

Because of the work and the time involved in taking these wire soundings, oceanographers eagerly sought an easier way to measure the depth. The answer was found by using a device called an echo sounder. I can remember an experience which vividly brought home to me the principle of this instrument. Aboard our research vessel we use powerful explosive charges to investigate the ocean bottom. While lying on my bunk below decks, I could hear these charges detonate in the water behind the ship with a resounding thump against the hull of the ship. Seconds later, if I listened carefully, I could hear another thud of sound much softer than the original explosion. This was the echo of the detonation bouncing back to the ship from the bottom—miles below.

The reason this echo can be heard, even above the noise of the running ship, is that water is an excellent and rapid transmitter of sound. One can readily verify this property of water by submerging their ear in a swimming pool or bathtub and then striking two hard objects together. Notice that the sound seems much sharper than normal. This is because water carries high pitched sounds much better than does air. This sound travels through the water at 4800 feet (nearly one mile) a second, or four times faster than air.

With hearing devices more sensitive than the human ear (which itself is extremely sensitive), sound far less powerful than an explosion of TNT can be heard after it has bounced back from the ocean bottom. Modern sounding equipment uses short bursts of a high-pitched sound or "pings" which are produced electrically at one-second intervals. The fathogram shown in Figure 1 was produced by continually recording the original "pings" and their echo as the ship moved through the water.

The record shown here outlines the top of a broad mountain, the crest of which lies 5400 feet below the surface. This mountain lies in the Indian Ocean not far from Western Australia. It rises from a basin about 16,000 feet deep. The mountain is therefore nearly 11,000 feet high and about 100 miles across at the base (a sizable peak by any standard). But this is just one feature of the many thousands which make up the shape of the ocean floor.

The map on page 7 shows one of the best explored portions of the ocean, and yet much of the chart shown has been filled in by interpolating between fathograms taken many miles apart. In many parts of the world today almost no soundings exist, leaving great voids in our knowledge of what the surface of the earth really looks like.

The echo sounder gives a large-scale picture of the ocean floor. What does it look like close at hand? A few scientists have seen the bottom at the deepest part of the ocean with their own eyes by descending inside the remarkable diving machine, the bathyscaphe. These scientists, as you may remember, reported seeing animals living at the bottom—almost seven miles below the surface. However, the bathyscaphe is an expensive instrument of exploration, as it can only explore a small area of the ocean floor. To get more coverage per dollar of effort, oceanographers must use simpler, more flexible instruments.

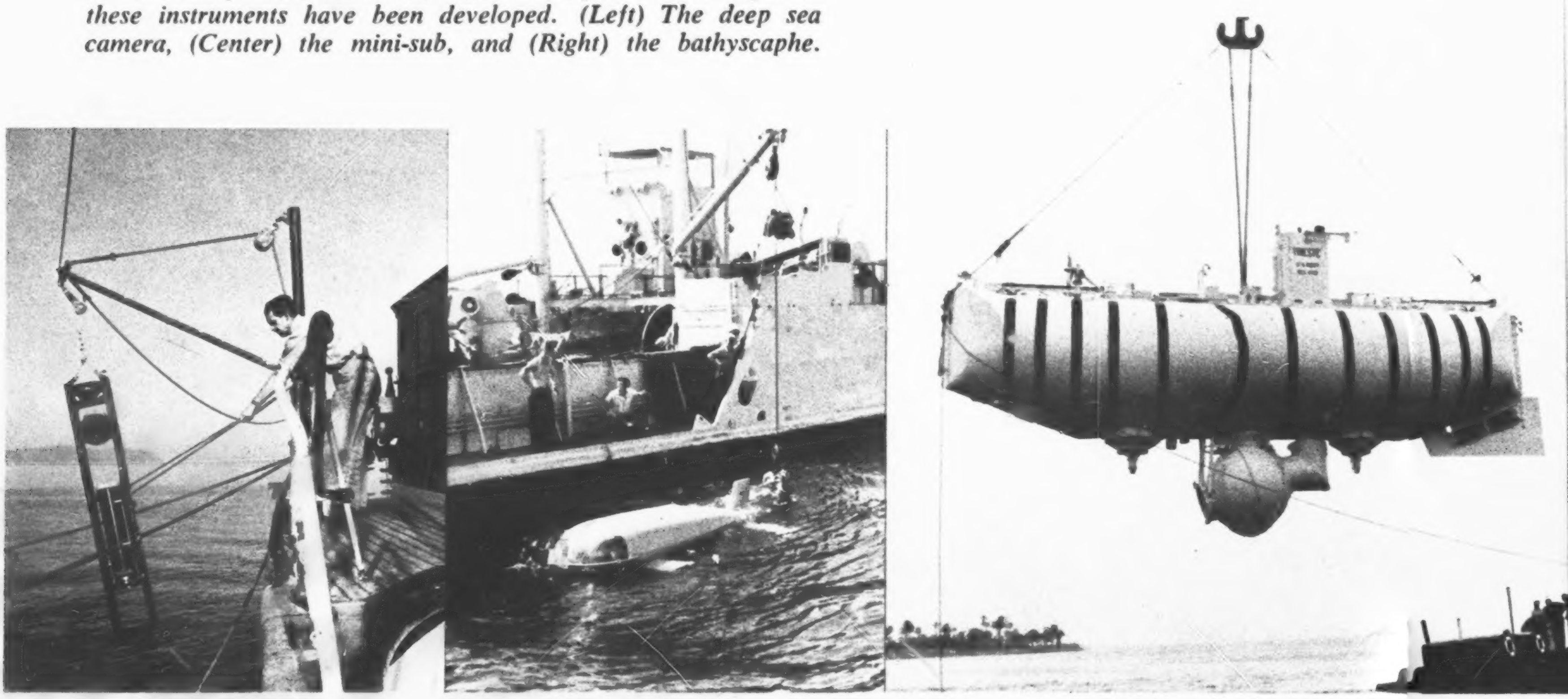
Such an instrument is the underwater camera. When people visit our research vessel, they often remark at the simplicity of the camera we use. It is a common 35mm camera, protected against pressure by a strong aluminum vessel, provided with a strong light, and a trigger to flash the light and wind the film when it makes contact with the bottom. Needless to say, constructing a camera to operate in the hostile environment of the deep ocean requires great skill and ingenuity. The simplicity of this instrument is a great asset, for it can be used over and over with great facility.

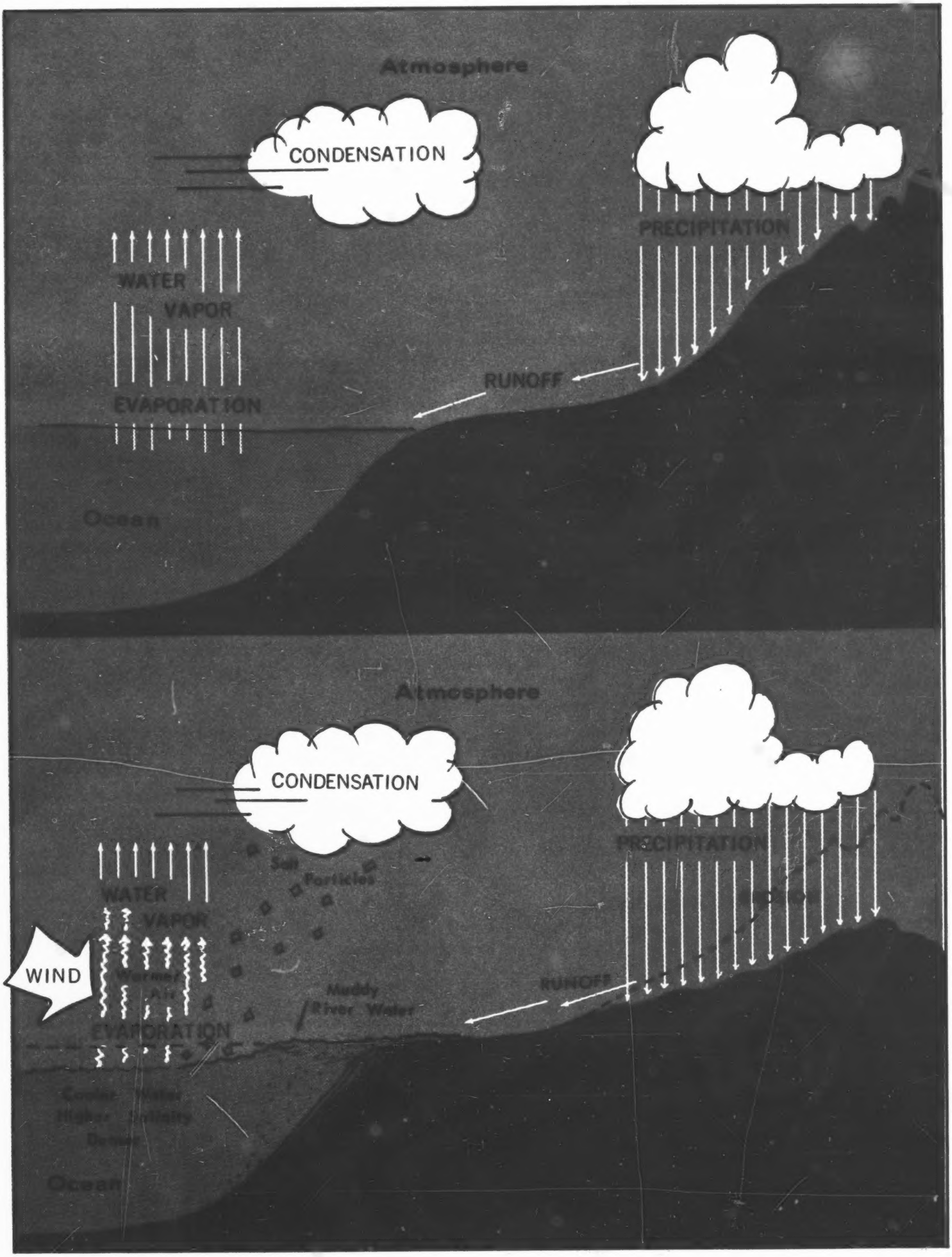
Many photographs of the ocean floor have been made in recent years, although like soundings of the early days they are still far apart, but they are the best close-up look at the ocean bottom. Figure 2 shows two photographs taken in the deep sea in over 9000 feet of water. From such photographs we have learned that some types of animals—namely starfish, sea worms, shellfish, and others—can live at any depth in great abundance. In some photographs, we have seen volcanic rocks and lavas, so that we know that volcanic disturbances are important in forming the features of the ocean floor. A close-hand look at the sediments tells us that the water of the bottom is in motion and sediments sometimes shift around the bottom like drifting snow. In brief, we can see that the ocean floor is far from being still and dead; but is an active place of life and movement.

Important also is the collection of samples of the sediment on the ocean floor. Many devices which can be lowered to the bottom to obtain a sample have been made, but the most successful is the corer. This is a long pipe which can be driven into the bottom sediment, usually with a great weight; and when the pipe is extracted, it brings the sediment penetrated back with it. Such corers, with luck, can penetrate the sediment up to 60 feet below the bottom. Because sediment is deposited so slowly, this gives us a chance to examine sediment which was laid down millions of years ago buried deep in the core sample. Careful examination of these samples has told us much about what the ocean and the earth were like in the past.

One of the questions ocean scientists would most like to be able to answer is: Is the ocean floor part of the original earth's surface, protected from the forces of erosion like wind and rain by the deep ocean waters? If it is, a careful study of the ocean floor would help us reconstruct what our planet looked like at birth. This is just one of the many exciting questions and possibilities which make exploring the ocean floor a real scientific adventure.

*In order to provide man with means to explore "Inner Space," these instruments have been developed. (Left) The deep sea camera, (Center) the mini-sub, and (Right) the bathyscaphe.*




Atmosphere
CONDENSATION
PRECIPITATION
WATER
VAPOR
RUNOFF
EVAPORATION
Ocean
Atmosphere
CONDENSATION
PRECIPITATION
Salt
Particles
WATER
VAPOR
WIND
Warmer
Air
Muddy
River Water
RUNOFF
EVAPORATION
Cooler Water
Higher Salinity
Denser
Ocean

# Oceanography and the HYDROLOGIC CYCLE

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The oceans are without a doubt a dominant physical feature of our planet, and in all likelihood, are unique in the solar system. Certainly, the earth would be uninhabitable were it not for the presence of the oceans; and life, which had its origin in the vast chemical soup bordering the continents, probably would not have formed or survived without the moderating influence of the oceans on the world climate.

Scientific exploration in the oceans is difficult at best, and it has only been with the advent of new electronic techniques in recent years that man's efforts to study the sea have been more than primitive. Today, however, we are beginning to realize the importance of the oceans. During this century we have learned that the sea, land, and air have a tremendous effect on each other. The interrelationship between the sea and the atmosphere is so complex, that some meteorologists consider them part of the same medium, separated only by a discontinuity in density.

## Land-Sea Relationship

As for the land-sea relationship, on the one hand material eroded from the land ultimately is deposited in the sea, and on the other hand much of the land on which we live was at one time the ocean floor. Because the three realms—land, sea, and air—are so mutually interdependent, any comprehensive study of earth science must include the sciences of geology, oceanography, and meteorology.

A simple means of coordinating studies of the three disciplines is through use of the hydrologic cycle. Most of us have seen this cycle depicted by a simple two-dimensional diagram (Figure 1) in which water vapor is added to the atmosphere by evaporation from the ocean; the water vapor condenses to form clouds; precipitation from the clouds brings water to the land; the water is returned to the sea as runoff through rivers and streams.

## Other Factors

This seems an extremely simple concept—but let us examine it to see if it really is so simple. In the first place, what effect does evaporation have on the ocean and on the atmosphere? When the surface water of the sea evaporates, there are two immediate effects; the water left behind becomes saltier, because only the water and not much of its included salt is added to the air; the remaining water becomes colder, due to the loss of heat during the evaporation process. (You may be familiar with evaporation devices used as air-conditioners and water coolers in dry climates.) The heat that is lost from the ocean is added to the atmosphere, thereby warming the air adjacent to the water. More than half of the heat transferred from the ocean to the atmosphere is transferred through evaporation. The increase of salinity (salt content) and the decrease of temperature makes the remaining water denser (heavier per unit of volume). This means that cold salty water occupies less space than it would if it were warmer fresher water—*i.e.*, it is more compact. Because water has been lost directly to the air and because the remaining water occupies less space due to an increase in density, the surface of the ocean is actually lowered by evaporation. Therefore, we need to change the diagram by lowering the level of the ocean where evaporation is occurring.

Wind blowing "dry" air across the water surface greatly accelerates the evaporative process, so we should add wind to the diagram. As the wind blows, ocean waves build up, and if the wind is strong enough, foam is blown from the crests of the waves. The blowing of salty foam into the air results in the addition of tiny salt particles to the atmosphere and these particles act as nuclei around which water vapor collects and condenses to form clouds. Although most of the rain from these clouds falls back into the ocean, an appreciable amount falls on land, depositing salt particles. The wind, which plays such an important part in evaporation, is also responsible for generating and driving waves across the ocean toward the land. If these waves are large when they strike the shore, erosion will take place, and the shoreline will be "eaten away" landward. If the waves strike the shore at an angle, they will set up longshore currents, which move sediments along the coast, and create beaches, spits, and bars.

As the clouds pass over the land, and the rains fall, each raindrop does its part to erode the earth's surface. Tiny bits of rock and mineral are worn away and are carried by streams and rivers toward the ocean. Some of the minerals which make up the rock are soluble in fresh water, and are carried by rivers to the sea as dissolved salts, along with the sediments. This constant removal of material (erosion) ultimately lowers the surface of the land.

When the rivers reach the sea, much of the sediment is deposited on the ocean bottom to form a delta or river-mouth bar. If the wave energy striking the coast is strong, the sediment will be distributed widely over the sea floor; if the energy is relatively weak, a delta, such as that of the Mississippi River, will form. The fresh, relatively light river water, carrying suspended sediment and dissolved salt, floats on top of the heavier sea water, and if the river is large, may extend many miles to sea as a "plume" of muddy water. Eventually, of course, the river water mixes with the sea water, and the sediments settle to the floor of the ocean. Thus, although the rivers tend to dilute the oceans by adding fresher water to it, they are actually balancing the cycle by returning water and salt to the sea in exchange for the water and salt carried by wind to the land.

When these details are added, the diagram is no longer quite so simple, but we are still dealing with only a rough two-dimensional picture (Figure 2). Addition of a third dimension would give the diagram added perspective. The degree of complexity of the three-dimensional picture is determined to a large extent by the magnitude of the third dimension. On a large scale, we must consider planetary winds; horizontal and vertical oceanic circulation; irregularities of sea surface elevation, temperature, and salinity (changes caused by many factors including evaporation, ice melt, and river discharge); topography of the land; variations of rock type, which determine the nature of the sediment and salt added to the sea; geologic forces which uplift the continents and keep them from being completely washed into the sea; and so on.

Examination of the hydrologic cycle in more and more detail makes it increasingly obvious that studies of the atmosphere (meteorology), the land (geology), and the sea (oceanography) are extremely interdependent. We cannot fully understand any one without some knowledge of the others.

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U. S. Navy Hydrographic Office
Washington, D. C.

# IQSY—
# *The International Years Of The Quiet Sun*

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On January 1, 1964, a new international cooperative scientific research program began—the International Years of the Quiet Sun (IQSY). This program will continue until December 31, 1965, with scientists from 62 nations participating.

IQSY is a direct outgrowth of a recent program (from 1957-1958) known as the IGY, or International Geophysical Year. During the IGY, scientists from many nations studied the earth, its structure, surface waters and ice, atmosphere, and relationship to the sun and space. Upon the conclusion of the IGY, the scientists realized the value of this type of international activity and that the many discoveries made uncovered more questions than answers.

Establishment of the dates for the IGY were to encompass the time of maximum activity of the sun and, indeed, it took place during the greatest activity witnessed in over 200 years of observing. In thinking about new programs suggested by the success of the IGY and the host of new geophysical problems before them, scientists decided to plan a similar program, but limited to studies involving the influence of the sun on the earth during the time when the sun is quietest.

What is to be gained by a concentrated research program during the quiet solar years, and what is meant by the term quiet sun? Before we examine these questions, a few facts about the sun and its influence on the earth should be noted.

First of all, the sun is a star, our nearest star in the universe, some 93 million miles distant from us. At this distance, an object the size of the earth intercepts approximately only one two-billionths of the solar energy that streams in all directions into space. The sun's warmth and light are apparent to us all, but it is not generally appreciated that most of our energy sources stem directly from the sun. Hydroelectric power, for example, is possible because the sun's heat causes water to evaporate: the water vapor circulates in the atmosphere and eventually falls as rain. Some of the rain falls on the uplands from which great rivers rise and run to the sea, thus providing the driving power for electric generating plants. Sunlight is the crucial ingredient in photosynthesis, and our oil and coal deposits originate in the plant life of the carbonaceous period millions of years ago. Only nuclear energy, which is just starting to be used in significant amounts, is independent of the sun.

### Surface and Interior Temperatures

The temperature near the surface of the sun is only some 10,000° F., while the temperature in the interior may be many millions of degrees. A layer of very turbulent gas surrounds the sun. This 6,000-mile thick region, called the chromosphere, is at a temperature of perhaps 50,000°-100,000° F. The bulk of the sun's atmosphere, however, is a far-reaching gaseous envelope called the corona. Temperatures in this region may reach millions of degrees. The solar corona extends millions of miles, perhaps as far as the orbit of the earth.

Most of the sun's energy is radiated in the region of the electromagnetic spectrum (see Figure 1) that is visible to the human eye. Complete solar radiation, however, extends over a wide spectrum including ultra-violet, X-rays, gamma radiation, and radio waves. These radio waves opened the doors to a new field of solar-radio astronomy, thus permitting scientists to obtain additional and invaluable clues on the nature of the solar atmosphere and its disturbance.

## A Quiet Sun

Sunspots are a convenient measure of solar activity, although it is not understood why. (Sunspots appear to be solar gas in rapid, spiral motion. The gas usually moves outward from the sun's interior, expanding and cooling itself as it spirals outward into regions of lower pressure. These sunspots appear to be gigantic whirlpool-like structures in the gases of the sun's outer layers, in many respects similar to the cyclonic storms of the earth's atmosphere.) These peculiar structures on the sun's surface (if a layer of hot, turbulent gas can be called a surface) increase and decrease in number in a fairly regular cycle that takes approximately eleven years. (See Figure 2.) In addition, as sunspot activity declines from a peak and reaches a minimum, a definite end of a cycle occurs. There is an overlap between an old and a new sunspot cycle, which can be distinguished by the trained observer.

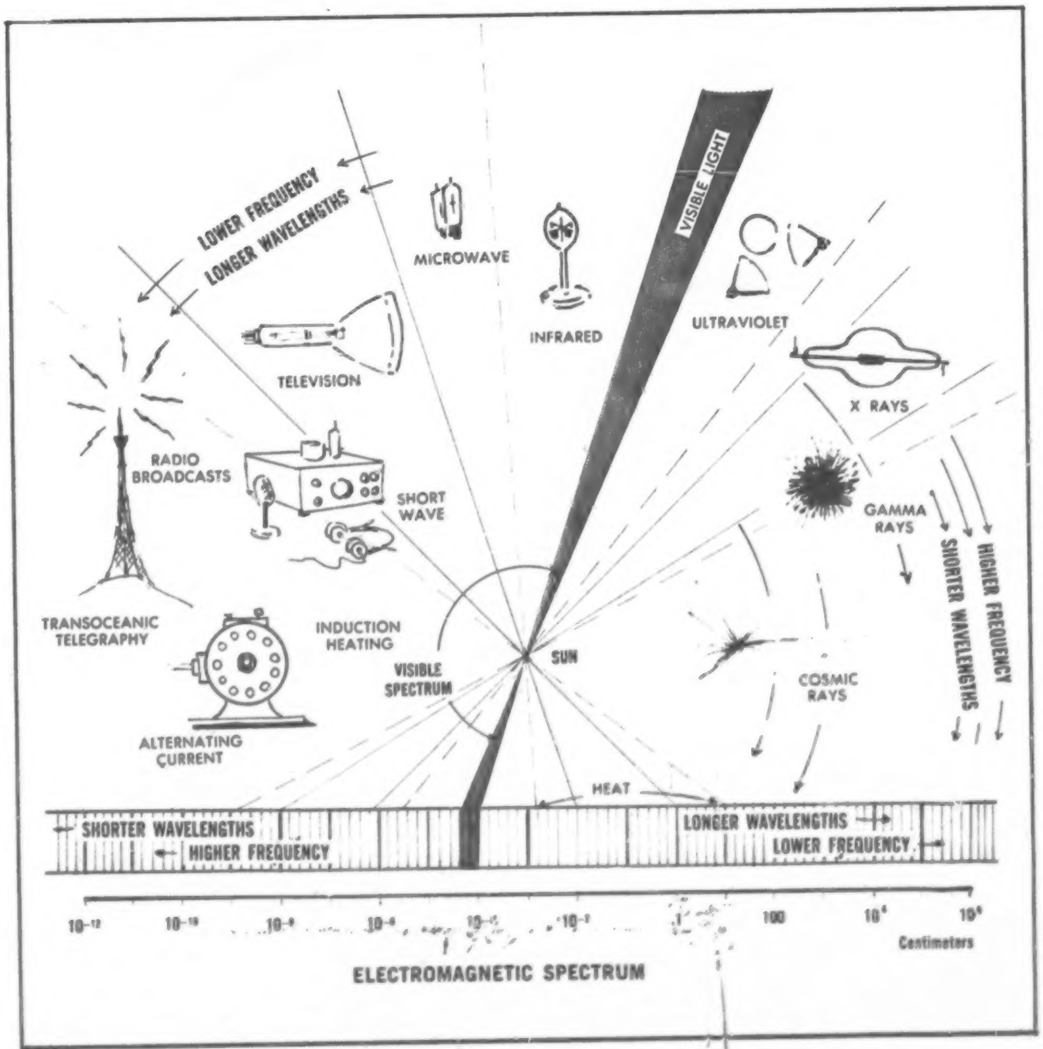
Ultraviolet radiation and X radiation from an undisturbed sun are absorbed in the upper part of the earth's atmosphere. These radiations are energetic enough to cause intense electrification of the earth's atmosphere at a height of 40 to 300 miles above sea-level. This area is referred to as the ionosphere and makes it possible for us to have long distance, including transoceanic, radio communication. (The ionosphere acts as a reflector of radio waves in a certain range of frequencies. Radio waves in these frequencies are transmitted from one station, bounced off the ionosphere, and received in another part of the world.) At times, great storms on the sun cause electrical disturbances in the ionosphere and upset our radio communications. Solar storms are more frequent when the sun is at or near maximum activity.

Solar radiations are responsible for heating the outer atmosphere (the lower atmosphere is heated mainly by light that is absorbed at the earth's surface, thus heating the water and soil and then heating the atmosphere above), which is hotter at solar maximum, and hence expanded, than it is at solar minimum. It is necessary to understand the entire atmosphere in order to better understand the lower portion.[1]

During the quiet years that will encompass the period of IQSY, scientists will be exploring the atmosphere with all the techniques at their disposal. Ground measurements are still very useful, for while some of the ground observations are not as direct as could be desired, they can be made continuously and by investigators in all countries. Balloons will carry special instruments to measure not only temperature and winds aloft, but to measure the concentration of important trace constituents like ozone and to study the incoming and outgoing infrared energy that determines the earth's heat budget. In addition, it will be possible to study certain kinds of large perturbations, such as the sudden warming of the stratosphere that often takes place in spring in the Northern Hemisphere, heralding the change in wind patterns from the stormy winter to the more pleasant spring. Every year is not the same, as far as weather goes, and it is becoming more and more important to understand why, and the nature of the mechanisms involved. Rockets and satellites will carry instruments into the atmosphere, up to the fringes of the earth's atmosphere, and beyond.

Also, during the quiet years, the sun is not really absolutely quiet. There are still some sunspots and some disturbances that produce storms, radio blackouts, auroral displays, etc., in the upper atmosphere; in the quiet solar years such dis-

*FIGURE 1. Notice what small fraction of the total range of wavelengths or frequencies is in the visible region.*


LOWER FREQUENCY
LONGER WAVELENGTHS
MICROWAVE
VISIBLE LIGHT
INFRARED
ULTRAVIOLET
TELEVISION
X RAYS
RADIO BROADCASTS
SHORT WAVE
GAMMA RAYS
HIGHER FREQUENCY
SHORTER WAVELENGTHS
TRANSOCEANIC TELEGRAPHY
INDUCTION HEATING
VISIBLE SPECTRUM
SUN
COSMIC RAYS
ALTERNATING CURRENT
HEAT
SHORTER WAVELENGTHS
HIGHER FREQUENCY
LONGER WAVELENGTHS
LOWER FREQUENCY
10⁻¹²
10⁻¹⁰
10⁻⁸
10⁻⁶
10⁻⁴
10⁻²
1
100
10⁴
10⁶
Centimeters
ELECTROMAGNETIC SPECTRUM

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[1] This point is explained very well in the films, *Our Mr. Sun*, which may be obtained by calling your local telephone company's business office, and *The Nearest Star*, produced by McGraw-Hill Book Company, Text-Film Division, 330 West 42nd Street, New York City.

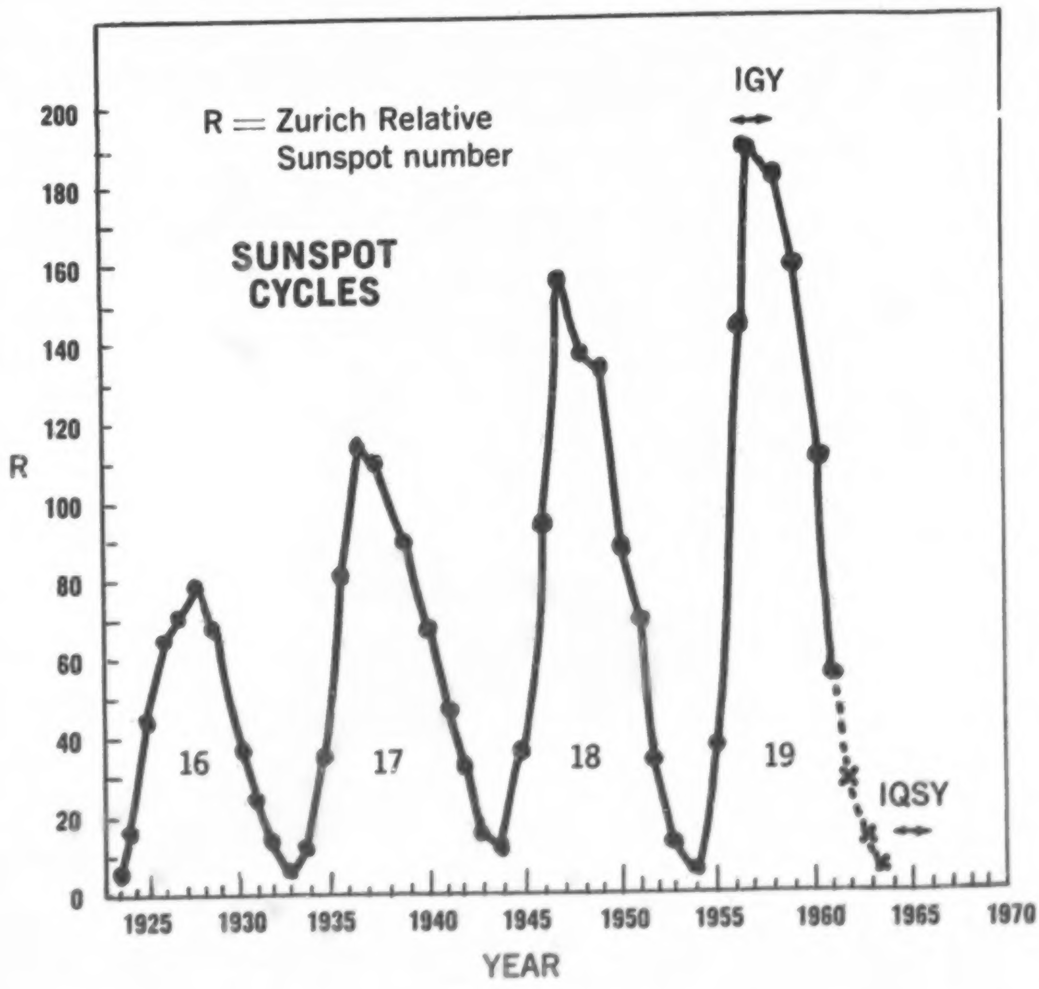
turbances are likely to occur in isolation, thus permitting the scientists to study them in great detail. Observations of the initial phases of the disturbances and the resulting terrestrial events are needed in order to develop further the theoretical understanding of the solar-terrestrial relationships.

Besides studying the atmosphere in its least disturbed state, and studying isolated cases of disturbances, there are some scientific problems that can be attacked only, or best, during the quiet solar years. For example, at this time the ionosphere is least opaque to radio waves from the sun and cosmos, thus opening up several more octaves for the radio astronomer. Also, when the sun is most quiet, the tenuous gas that fills the interplanetary space is the least disturbed and there is less shielding of cosmic rays, especially the lower energy cosmic rays. The study of cosmic rays is important to theories of the origin of stars, galaxies, and the universe itself, and they are also powerful tools for the study of the interplanetary gas and the outer atmosphere of the earth.

## Special IQSY Calendar

A special calendar has been devised for IQSY, which designates each Wednesday as a World Day, and also sets aside nine two-week periods during IQSY for concentrated study. This selection of days and periods is to afford a means of coordinated observations, especially those that cannot be made every day because manpower is limited, the observations are too expensive, or because the techniques are still experimental. In addition to days that can be chosen in advance, a worldwide alert system is continuing from the IGY with some important modifications. For example, in IQSY, it will be important to designate especially quiet periods for the benefit of investigators who wish to study small effects.

*FIGURE 2. The diagram shows the probable decline (dashed curve) of the recent cycle of activity and the time period of the IQSY.*



Each day during IQSY, a message will be relayed around the world using radio, telegraph, and teletype systems. In each country, local arrangements are made to distribute the message to interested scientists. The messages are relatively simple such as "MAGSTROM," meaning that a large magnetic storm is in progress or is predicted to take place during the next twenty-four hours, or "SOCALME," meaning that there are no sunspots or active regions on the sun and no disturbances should occur for several days. These simple messages, with years of experience and intense planning behind them, will trigger special observations and experiments that will markedly increase our understanding of the sun and how it controls the environment of our planet. In addition, continuous and routine observations of the ionosphere, the earth's magnetic field, the motion of the atmosphere, and other related geophysical phenomena will complete the intense cycle of study and research begun in the IGY.

## Never-Ending Search

It is not safe to predict the discoveries that will be made in IQSY, nor to discuss benefits to mankind, such as better weather forecasting. All basic research and investigation of natural phenomena are bound to have applications eventually. It is safe, however, to predict that the IQSY will have an important influence on our knowledge of our planetary environment and that as new understanding is applied to problems that we can formulate now, new questions and problems will be uncovered that will be more challenging and interesting. It seems that there will never be a lack of scientific problems for students to tackle.

ARENDROLAND COMET

HALLEY'S COMET

# Comets

**GERALD PEASE**

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For centuries, the appearance of a comet was considered a dread harbinger of war, pestilence, famine, earthquake, or the death of kings. In Shakespeare's words:

> When beggars die, then are no comets seen;
> The heavens themselves blaze forth the death
> of princes.*

Before the late 16th century, most European astronomers regarded comets as a sort of vaporous exhalation within the earth's atmosphere. It remained for the Danish nobleman and astronomer Tycho Brahe (1546-1601) to demonstrate that they were more distant than the moon, and were true heavenly bodies.

The sighting of comets was reported as far back as 4000 years ago in China, and shortly thereafter in Babylonia. In our times, comets are sought out by amateur astronomers who pursue the nocturnal sport of comet hunting, and their existence is confirmed by astronomical observatories. Pons, the most successful comet hunter of all, who discovered 37 comets between 1801 and 1827, was a doorkeeper of the Marseille Observatory in France.

A typical comet consists of a nucleus, a coma, and a tail. The nucleus is extremely small and sometimes barely discernible. The coma is that part which usually sloughs off to form a tail. An average coma may have a diameter of about 80,000 miles; one observed comet boasted a coma 1,255,000 miles in diameter—a larger diameter than that of the sun. As for comet tails, the largest one observed streamed out across space for a distance of about 200,000,000 miles—approximately the distance from the sun to Mars. In cross section, comet tails may often measure up to a half million miles in diameter.

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* William Shakespeare. *Julius Caesar.* Act II, Scene II.

Less than a millionth part of a comet's mass is in its coma and tail at any one time. The nucleus, a dense solid body, or conglomerate of bodies no more than a few miles in diameter, contains virtually all the mass. It is believed to consist of a mixture of various ices (water ice, dry ice, frozen ammonia, frozen methane, and others) with mineral debris and dust—all combined at low temperature to form what astrophysicist Fred L. Whipple has called "a dirty snowball."

As a comet approaches the sun, the ices evaporate under the influence of the solar radiant heat. The vapors and dust leave the nucleus in all directions to form the coma. Partly because of solar radiation pressure, and perhaps because of the solar wind, the gaseous molecules of the coma are formed into a tail. A coma's tail always points away from the sun, trailing away from the head when the comet is approaching the sun, and preceding it when going away from the sun.

Particulate matter embedded in cometary nuclei has been identified, spectroscopically, as sodium, iron, nickel, and chromium, although most of it must be ferromagnesian silicates such as those found in meteorites.

One interesting aspect of cometary phenomena is the possible relationship of a comet's chemical constituents to life itself. If some cometary compounds, such as ammonia, water, methane, and diatomic hydrogen are subjected to an electrical discharge, a variety of complex organic compounds are produced, including amino acids, that are involved in the life processes of living organisms. The ancients regarded comets as harbingers of disaster. Modern science *may show* them to be, in some respects, the progenitors of life.

* * *

# Planet Number Ten?

**FRANKLYN M. BRANLEY**

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Have you heard or read about the discovery of a new planet? Do you think that this new planet is a member of our solar system? I hope that you have not told your class that there are now ten planets in our solar system instead of nine, because such is *not* the case.

A new "planet," or object that behaves like a planet, has been discovered, but it is outside of our solar system. This object is associated with a star about six light-years away from us—about 36 million, million miles.

Peter van de Kamp and his associates at Swarthmore College, Swarthmore, Pennsylvania, announced in the summer of 1963, that Barnard's Star was really two objects. Astronomers have known about the existence of Barnard's Star for some time now. In the past 25 years, 2413 photographs have been made of this star. (Astronomers learn more from photographs made through telescopes than looking directly through the eyepiece of the telescope. The photographic-plate can be exposed to one point for long periods of time and the light from the object in space can be, so to speak, gathered on the plate. The photographic-plate accumulates light, while the human eye is unable to do this.) The photographs of Barnard's Star were studied carefully by van de Kamp and his associates, and they noticed that a waviness in the star's motion occurred regularly. These changes in position of the star, detected in the photographs, were carefully measured. The amount of change indicated that Barnard's Star had a companion with a mass 1.5 times that of Jupiter.

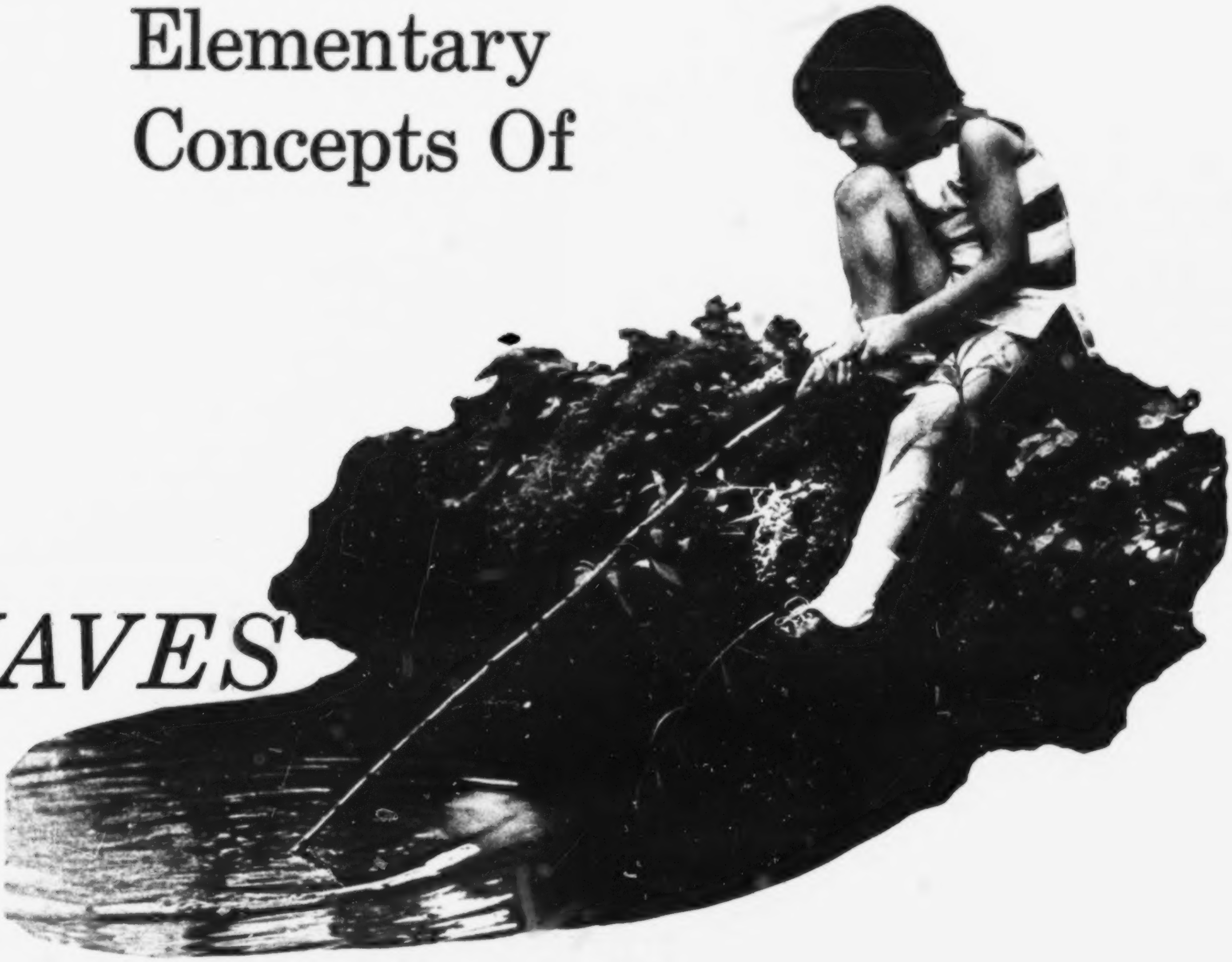
Stars, as you know, are gaseous masses with interior temperatures of some 14 million degrees. A body with a mass 1.5 times that of Jupiter could not have such a high central temperature. This evidence led the astronomers at Swarthmore to conclude that the companion object cannot be called a star. They also noted that an object with this mass (1.5 times that of Jupiter) must shine by reflected starlight, or as we say, sunlight. The companion object is so dim that a human could not see it with even the most powerful telescope, but the mass did appear on the photographs.

Other stars are known to have companions that cannot be observed, however, the companions have always been very large masses. Bernard B, the name of the companion, is much less massive. In many respects, Barnard B and Barnard's Star may be compared to Jupiter and the sun.

There are probably millions of other stars in our galaxy which support planets or planetary systems. However, accurate observations made over long periods of time are required to prove their existence.

For further information, read the article by Peter van de Kamp "Barnard's Star as an Astrometrics Binary," *Sky and Telescope,* July 1963, p. 8.

# Elementary Concepts Of *WAVES*



**J. N. SHIVE**

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Scientists know that light and sound, modern communication, the furnishing of electric power to our homes, and the destruction of life and property by earthquakes or ocean storms are all manifestations of wave behavior. The importance of waves and the roles they play in our physical world, however, are often unrealized by people who use them every day of their lives. And children in our elementary schools are among the people who use waves.

Particularly fascinating is the great variety of types of waves; e.g., light waves, sound waves, electric waves, radio waves, water-surface waves, even waves of chemical reaction along nerve fibers. Equally wonderful is the diversity of ways in which waves are generated. Wave sources are found in such things as a glowing lamp, human vocal cords, a policeman's whistle, a moving ship, the sun, a faulting block of the earth's crust, and the nucleus of an atom.

Diverse though waves may be in type and method of generation, there are aspects of behavior which are exhibited in common by waves of all kinds. Of such aspects there are many, but the ones listed below seem most suitable for presentation in the elementary grades.

**Amenability to Definition**
**Propagation**
**Decay** (damping)
**Energy Transport**
**Speed**
**Independence**
**Reflection**

In discussing these topics with a class, the teacher can readily build upon children's experiences. While there may be nothing in a child's store of observations to suggest to him that light and sound are manifestations of wave behavior, such things as ripples on a pond, flapping flags, and, perhaps, even waves of grain stalks in a windblown wheat field are familiar to most children. Therefore, the youngsters have an already-formed idea of what a wave is. Upon this idea a teacher can build in many directions.

Such building may have at least four major purposes:

1. to teach some of the facts and develop some understanding of the physical world we live in
2. to sharpen the powers of observation
3. to stimulate children's natural curiosity about things and happenings
4. to develop the ability to relate and generalize

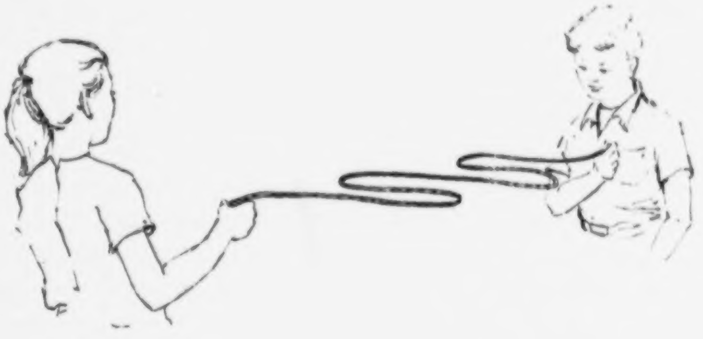
### Definition and Examples

Guide the children to recognize that a wave can be defined as *a moving disturbance of a medium from its normal condition.* Use additional words to fortify understandings of such things as "disturbance," "medium," and "normal conditions." Explain that the *medium* is the material *in, through, along,* or *on* which the wave travels. Light waves and radio waves, however, can travel in a nonmaterial medium—a vacuum or void.

The surface of a pond is a good example to start with. Its normal condition is to be flat and smooth. But if you throw in a pebble, you set up a point or center of *disturbance* of this flat and smooth condition. This disturbance travels outward from the point in all directions as a circular, expanding pattern of waves. Guided discussion can help children see that this pattern is always circular—never elliptical, rectangular, or otherwise misshapen. What does this mean about the wave speed in all directions?

### Propagation

A 20- to 50-foot length of rope makes an excellent medium for demonstrating *wave propagation.* The rope should be quite flexible (weathered for a few months or soaked in a couple of changes of boiling water to soften it). Go into the schoolyard and have two children hold the rope between them. They should pull the ends just hard enough to lift the middle of the rope off the ground. The normal condition of the medium in this case is to hang quietly, with a gentle sag in the middle. Have one of the youngsters give his wrist a quick flip sidewise. Notice that a disturbance in the form of a kink is introduced into the rope and that it travels quickly to the other end as a *transverse wave.** This wave can best be seen by the other children if they group themselves so as to be looking past or over the shoulders of either of the children holding the rope. This demonstration affords an opportunity to point out that although the wave travels along the rope, the rope itself does not travel with the wave. Each successive section of the rope merely wiggles back and forth, in place, as the wave travels over it.



This observation has its counterpart in all other forms of wave motion. The individual particles or

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* In transverse waves, the direction of the distortion is crosswise or at a right angle to the direction of travel of the wave.

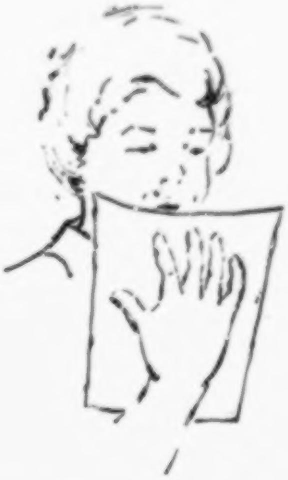
*Waves pattern the surface of a wheat field.*

units of the medium merely oscillate back and forth around their undisturbed positions as the waves pass by. The droplets of water on the surface of a pond bob up and down as the waves move along, but the water itself is not transported bodily with the wave. Electrons in the wires of a telephone circuit move back and forth as the electric waves representing your voice travel along the wire. Successive layers of air (actually the molecules themselves) in a room vibrate back and forth as sound waves travel through the room. This vibration can be felt if you shout loudly at a sheet of paper held just in front of your face. The vibrating layers of air communicate the vibration to the paper. Have the youngsters try this. Point out that although the paper shakes back and forth as the sound waves pass through it, there is no indication of a transport of air in the form of a wind blowing along with the sound waves.

### Damping

One of the fundamental properties of waves that can easily be taught and demonstrated is the dying out or *damping* of waves as they travel. Damping can be seen in the case of the waves in the rope. Notice the gradual decrease in *amplitude* (the size of the disturbance) that takes place during the time of one transit across the length of the rope. In this case, the damping is due to the internal friction of the strands of the rope which rub against each other as the rope flexes back and forth.

The waves of other wave systems similarly die out as they travel along. A pane of window glass is ordinarily thought of as transparent, but do you think that a flashlight beam would show through a block of glass 1000 panes thick? Light waves encounter "frictional" losses even in "transparent glass," which gradually absorbs the wave energy and causes the waves to die out. Through the clearest ocean water, sunlight can penetrate only a few hundred feet. How about in the muddy water of the Colorado River?



About the only waves for which there is no damping at all are the electromagnetic waves in absolutely empty space. Otherwise, the starlight from distant nebulae would never reach us through the thousands of millions of miles of interstellar distance. But even this space is not *absolutely* empty. The absorbing and scattering effects of cosmic dust and stray molecules reduce the light that actually reaches us from the stars.

### Energy Transport

All waves are carriers of energy. To elementary students, energy can be explained as something that enables us to see, hear, feel, or do (run, talk, lift). Energy which is fed into a wave medium by a generator of waves can be obtained from a medium somewhere else and made to do something that registers on our senses. For example, the child who launched a wave onto the rope by flipping his wrist generated the energy necessary to get the wave started. This energy was fed onto the rope in the form of the distortion, which was the wave. As this distortion traveled along the rope, the energy traveled along with it; and this energy was delivered, a short time later, in the form of a jolt in the hand of the youngster who held the other end of the rope.

In a telephone conversation, the speaker's words are converted into electrical waves which travel along the telephone wires, delivering at the other end the energy necessary to activate the earpiece of the listener's instrument, perhaps 500 miles away. There, this energy is converted into sound energy which, in turn, is expended in vibrating the listener's eardrum and setting into action the processes of hearing.

The energy transported by a beam of light from the sun is easily detected by the heating it imparts to objects the light falls upon. Some of the energy of a hurricane at sea is converted into the energy of ocean waves which can destroy property along the seacoast a couple of hundred miles away and a few hours later. (Even without such experiences to call upon, it should be evident on philosophical grounds that we cannot have a wave of any kind without having energy involved. By definition, *a wave is a disturbance*. It requires energy to produce the disturbance in the first place. And if the disturbance moves from here to there, the energy must go along, too.)

### Speed

The experience with the rope may call forth some remarks from the youngsters about the speed of propagation of the wave. "Real fast!" "Faster than you can run!" Indeed, a youngster may want to run beside the rope to see whether the wave does go faster. Suggest that he get up to full speed as he runs past the youngster holding the end of the rope and that the latter flip a wave onto the rope at the instant the runner passes him.

Suggest some other experiments with the rope. Do big waves travel faster, slower, or at the same speed as little waves? Does the speed change when the tension or pull on the line is changed? Does a given size wave travel at the same speed in a thick rope as in a thinner one?

Turning to other kinds of waves: How would conversation be affected if loud sounds (big waves) traveled faster or slower than soft sounds (little waves)? How would long-distance telephone communication be affected if the electrical waves of different sizes and shapes, representing sounds of different loudnesses and pitches, traveled with different speeds along the telephone line?

Back in the classroom again, discussion and reading can lead to ideas of the dependence of a result upon the conditions of the system and the generalized relationship between a dependent variable and an independent variable. Invite pupils to think of other examples of such relationships as "the faster you travel, the sooner you get there," "the hotter the soup, the longer it takes to cool," "the louder you shout, the farther you can be heard," "the thicker the beam, the more load it will carry."

*Interpenetrating ripple patterns are produced when two objects are thrown into the water side by side.*

The length and depth to which you can go in such lessons will depend, of course, on the grade level of the children in your class. However, the idea of *qualitative dependences* can be taught at an early age and should be attempted. In the upper grades, some of these dependences should be put into *quantitative* terms. If a youngster can learn in arithmetic that the volume of a rectangular solid is a product—of length, width, and height—he should be able to learn in science that travel time is a quotient—distance traveled divided by speed.

### Independence

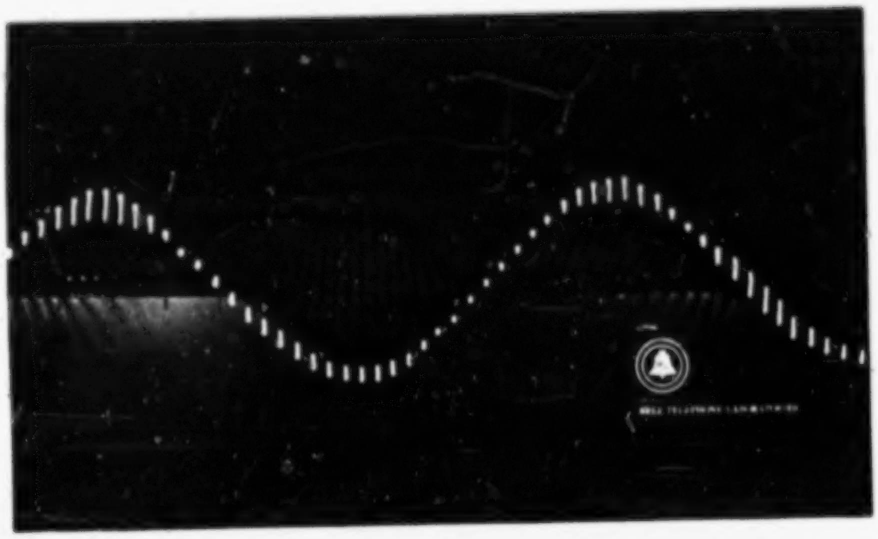
Raise the question of what will happen if two waves are started simultaneously at opposite ends of the rope. A few trials will show that the waves travel in opposite directions, meet at the middle of the rope, pass through each other, and keep right on going. This property of *independence* is a characteristic of waves of all kinds.

In a room full of people talking, there are sound waves traveling in all directions. The waves of each conversation go their own way quite independent of the simultaneous presence of waves from other conversations. Two pebbles thrown side by side into a quiet pool of water produce circular ripple patterns which interpenetrate but keep on spreading out independently.

Waves, unlike material objects, do not collide and deflect each other from their original courses. This behavior, so contrary to general experience with bodies in motion, is possible because a wave is not so much a *thing* as it is a *condition*, and conditions are superposable.

### Reflection

Instead of two pupils holding the rope, tie one end of it to a solid object such as a tree trunk or a fence post. Now, if the rope is pulled tight enough to clear the ground and a wave is launched upon it, the wave will



*Various methods have been developed to simulate wave action in the classroom. The device on the left is used to study waves in the form of water ripples. The wave machine shown above, is used to illustrate and study varying speeds and sizes of waves.*

travel to the end and bounce back to the sender. He will feel in his own hand the jerk which the returning wave delivers to him, and the other children will see the wave both going and coming back. They have seen an example of *reflection*.

Most youngsters will already have experienced optical reflection and acoustic echoes, but they will probably be fascinated by the idea of actually seeing a wave being reflected. Here is the opportunity to point out to them the similarities among optical reflection, sound echoes, and what they have just observed with the rope. To strengthen the pupils' understanding of reflection, have them stand 150-200 feet away from a solid wall or building and have someone clap hands, once, loudly. In a fraction of a second the echo will come back. Repeat several times so all will discover what to listen for and hear the echo. Point out that there was a delay between the clap and the echo, just as there was a delay between the launching and the returning of the wave on the rope. With the rope experiment still in mind, the children will accept the plausibility of sound as a wave phenomenon, even though they have had no direct proof.

With older children the demonstration should not end here. It should be carried on to a calculation of the speed of the sound wave. How far were they from the reflecting building? What time (in seconds) did it take for the sound wave to get to the building and come reflecting back? If you can lead the children to a final value somewhere near 1100 feet per second, as by guiding their estimates of distance and time, they will probably feel very triumphant when they check their answers in a physics textbook.

### Conclusion

The exposition and the examples in this article outline some fundamentals of wave motion and offer suggestions on how elementary concepts of waves can be taught in the primary and upper elementary grades. Wave phenomena are so universal and are of such importance to human activity, that an early introduction to their nature might well be part of every child's school science experiences.

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**NOTE: Additional classroom activities and experiments in the study of waves are suggested in the 96-page publication, *Energy in Waves*, which has been produced by NSTA and NASA and published by Teachers Publishing Corporation. This volume is one of the six handbooks of the "Investigating Science with Children" series for the teaching of science in the elementary school. The books are available for $1.95 each or $10 per set from *The Grade Teacher*, Darien, Connecticut.**

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# Do Birds Have Dialects?

Does the nightingale in Nottinghamshire have a different song from its distant relative in Bordeaux, or the owl in Africa a note distinguishing it from the Japanese species? Do birds, in fact, develop regional "accents"?

According to Dr. W. H. Thorpe, an ornithologist from Cambridge, they do, although to the human ear their notes may sound exactly the same. At a recent meeting of the Zoological Society of London, Dr. Thorpe related experiments he had made with visual soundtracks, or spectrograms, to study the songs of birds of the same species from different regions. Distinctive intervals, harmonics, or transients were noted when the spectrogram was played back at quarter speed.

Nightjars in Africa, for instance, do not burble and churp in exactly the same way as they do in parts of England.

Since the hearing of birds is about ten times keener than that of humans, it seems probable that various species can detect these differences. Bird calls are linked with mating, and the differences are passed on from generation to generation.

UNESCO FEATURES

## SECTION 3 RESOURCES FOR THE TEACHING-LEARNING OF SCIENCE

### Introduction

It is not enough to be knowledgeable about the objectives of science education and the content of science. Teachers need resources in order to teach, and children need resources for learning. The purpose of this section is to suggest some teaching-learning resources and to present ideas for their effective use.

Resources are as diverse and as plentiful as the environment itself. People, places, printed materials, and equipment contribute to the implementation of a science program. Within any community are persons who have special experiences and knowledge to offer to children's learning of science. Whether a school district be urban, suburban, or rural, there are places which can be visited for the purpose of extending and deepening children's interpretation of environmental phenomena. Children turn to books and current materials for verification of first-hand experiences and for clarification and extension of ideas. These instructional materials also serve as motivators of interest for new experiences and new ideas. Equipment is needed for experimentation and other activities.

The articles which follow deal with the identification, selection, and utilization of the kinds of resources described above. In addition, there is an article about the preparation and evaluation of science handbooks for teachers, which are resources for teacher-planning of science experiences. Together, the articles offer increased insight in the optimum use and the evaluation of resources for the teaching and learning of science.

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# THE SPECIAL—

# *An Untapped Community Resource*

**DAN TREDWAY**

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Elementary school science is an area of the curriculum where members of the community can make an extremely valuable contribution toward the improvement of teaching. In every community there are individuals—who have some special hobby, interest, or proficiency related to science. Although such resource people have been used in classroom situations, their greatest value and most significant contribution to the entire science program can be through their working directly with groups of teachers.

Involving resource people in programs intended to improve elementary science instruction offers specific advantages. Since it is almost impossible to find a single teacher who has the breadth of background needed to provide subject-matter information in all science areas taught in the elementary grades, resource persons can be a source of specialized information for teachers. They may have specific information concerning the local area that is unavailable from any other source. Also, cooperation between a teacher and a community resource person will provide the teacher with continuing assistance and information in a science area as well as offer the resource individual a way to become involved in the school's instructional program.

### Careful Preprogram Planning Is Essential

Maximum use of local resource persons depends upon careful planning to insure effective contributions. The director and organizer of this kind of program must carefully select and orient the speakers. He or she must inform the resource people of the purposes and nature of the program in which they are participating, the science background of the teacher participants, and the particular contribution that the speakers might make. An outline showing the content, by grade level, of the science curriculum in the school would be an invaluable aid for these persons. For example, if a geologist is provided with a guide to the concepts in geology introduced in the curriculum and the grade level at which they are presented, he will be better able to plan his program.

Also, if the resource person is made familiar with the overall elementary science program, he will find it easier to communicate with the teachers at their level. When the speaker does not have an accurate knowledge of teachers' requirements, there is a real danger that his presentation will be on a level that teachers may not be able to use.

A program of this type should be supplemented with methods of translating and relating the information provided by the speakers into suitable experiences and experiments for children. This may be provided for teachers in workshop-type sessions where teachers of a particular grade level can work together or with a person who is designated as a group leader after each general presentation. Whatever the form of organization, this activity is a most essential part of assuring successful use of a community resource program.

To provide a clearer understanding of the types of information that may be gained from resource persons working with teachers, here are three specific cases.

#### I. Ornithologist

An amateur ornithologist met with an after-school class of elementary teachers to prepare a unit on living things. His contribution to this group included a brief discussion of bird migration and the bird population of the local community at various seasons of the year. He answered questions and provided specific information about bird identification and preparation of winter feeding stations. Then, he displayed and suggested books that were appropriate for teacher reference and for the use of children at various grade levels.

Following this lecture session, the group went on a short field trip to a wooded area nearby and, under the direction of the ornithologist, observed birds and discussed methods of providing this type of activity for children. The field trip was followed by a summary session which was directed to the selection of areas for trips with children and the suggestion of additional resource persons in the community who might speak on the subject or who might guide classes on field trips.

#### II. Military Officer

An interesting session was provided by a recently retired military officer who had been assigned to an aerospace program during his military career. He discussed the developments and purposes of several aerospace programs and then provided background information on their types of guidance systems, fuels, and future developments.

Teachers had the opportunity to raise questions—both theirs and ones they had been asked by children. The session provided background information in an organized form that teachers could apply to helping children evaluate new information on the subject as well as clarify misunderstandings.

#### III. Engineer

The engineer in charge of the city water purification plant helped a group of elementary teachers understand the water resources of the area and future needs of the community. The engineer took the group to the local facility where he described the sources of water contamination and its control and discussed sanitation problems, including the measurement of suspended sediment and radioactive materials contained in water. Following the explanation, he showed the teachers how the incoming water is pumped from the river through the various purifying and settling procedures until it is ready to be pumped into the system through the pumping station.

### Every Community Will Have Resource Personnel

These three cases cite only a few ways in which community resource persons can contribute to the improvement of elementary science instruction.

In most communities, at least some of the following resource people should be available: Audubon Society representatives, Forest Service and Soil Conservation Service employees, garden club representatives, trained biologists in many specific areas, meteorologists, amateur or professional astronomers, geologists or members of gem and mineral societies, chemists, ham radio operators, and many others. Some high school and college science teachers can make important contributions to such a program.

One of the most significant values of a community resource program is that teachers are aware of science outside their classroom and made specifically aware of ways that they can make use of the local area to further children's learning. The total effect of such a plan should result in a more vital instructional program with teachers that are better informed and equipped to use the resources around them.

# SCIENCE OUT OF DOORS

**MATTHEW BRENNAN**

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Pinchot Institute for Conservation Studies
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During the past school year, it has been my pleasure to walk with you along the trail, examining as we walked the myriad lessons which can be found along the way. We passed so many lessons that I want to go out with you again this year, to look again at some of the old places we have scarcely seen, to see what new trails we may walk along.

Why should you want to take your class outdoors? I could say that you owe it to your boys and girls to let them learn about the world about them, their place in it, how the living things in it affect their lives, and how man affects the living things around him.

I could say that ours is an outdoor heritage, and that the future citizens of this nation will need training in the use of the natural world around them and the sensible use of their leisure hours in it. Children who have learned to know the soils and rocks, trees, birds, and animals; children who have learned the beauty and wonder of the world, are never found standing idly in the midst of it all wondering what to do with their idle hours, minds, and hands.

But your principal or superintendent may want a "better" reason than training future citizens so they will not destroy their world, or sit bored in a picnic area or campsite in the midst of a majestic National Forest or Park because they have not learned to "see" the things around them. If he insists on an educational reason for approval of your field trip, tell him it is easier and better to teach some things outdoors by direct experience, and things learned by direct experience are never forgotten.

Some science lessons can only be taught by reading or films. For example, your students may never be able to live in Antarctica or see the sun's corona. These they can read about or see on film. But too many of our children are learning about clouds from a chart or pictures when beautiful specimens are floating overhead. Too many boys and girls are learning bird songs from a record when the real birds are singing just outside the classroom window. Too many of our students are learning about soil erosion by pouring water over soils in a classroom box when a piece of the school grounds washes away with every storm. Too many of us are singing "I love thy rocks and rills" when they do not know what a rill is. Do you know?

Teaching outdoors is just good teaching—teaching by direct experience. It is new and exciting. It is challenging. You will be asked questions you cannot answer. Do not be embarrassed. You can all learn them together. If you knew all the answers to the puzzles of nature and the world we live in, you would not be teaching where you are. I would call you to sit with me along the deep ravines and ancient hemlocks behind the Pinchot Institute, to answer my questions and those of the scholars who will visit here to learn a little more about how man can live in harmony with the land.

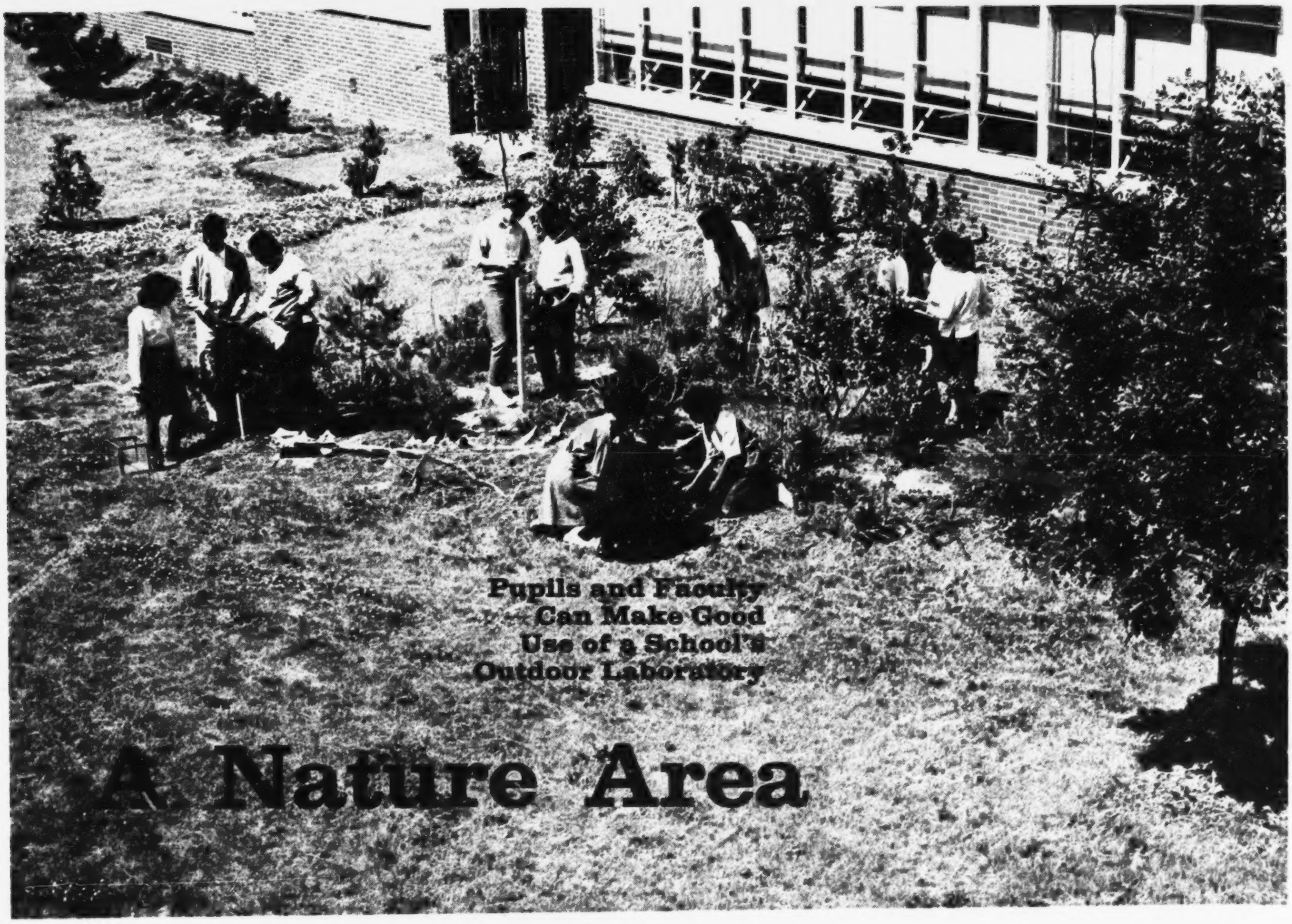
### Use Your Community Resources

But this is enough talk for one day. Let's go outside the school building and see what is out there that can be used in your science program this year. I wish I could walk with each one of you, but this cannot be done. Yet there is no need for you to go alone. Every community in America has a rock hound, a birder, a soil conservationist, a forester, and an extension agent. Seek them out. Tell them you are interested in using the things in the area around the school and in the community in your class program. You will be amazed at not only the quantity but the quality of help that is available for the asking.

Look around you. Whether your school is in New York City, the desert of Arizona, the rain forest of Washington, or the prairie of Iowa, you live in a kind of environment. Learn all you can about it. Learn about its soil, its water (supply and condition), its plants and animals. Most important, how are all these things related to one another, to the community, to you and your children, to the nation as a whole? Where does the water from your school ground come from? Where does it go? How about your crops, your woods, your minerals? What visitors come to live in your community and how do they get there—on the wind, on wings, in the back of someone's car, or as burrs on your clothing? What influence does their visit have?

Well, we are off at last on a new and exciting school year. Teaching is the most wonderful job in the world. It can also be a great deal of fun, especially in the outdoors, where you can come face to face with the world, its pleasures and problems.

See you on the trail!



## Pupils and Faculty Can Make Good Use of a School's Outdoor Laboratory

# A Nature Area

**ERLING W. CLAUSEN**

Superintendent of Schools
Freehold, New Jersey

An outdoor laboratory—a natural area right on the school grounds—stimulates the interest of both students and teachers in all subjects. We have found this to be true with the artificial "natural" center established on the grounds of our Intermediate School.

A natural outdoor center—an area just as nature designed it—is best, as well as cheapest. To have that kind of outdoor facility, it is necessary to set aside part of the grounds before work on constructing the school building begins. (Long before the bulldozers start tearing up the earth and ripping out trees and brush.)

However, in our case, the school building was already up and we had to be satisfied with a miniature artificial "natural" area due to limited acreage. An artificial outdoor laboratory on the school grounds can serve many useful purposes and it has certain advantages.

To get the full benefit of an outdoor laboratory, students and teachers must be able to use it daily or at will. Students become most interested and gain the greatest benefit from such an area when they can study, observe, and probe by themselves. They can do that only when the outdoor facility is handy, available for their use at all times. Taking a class on a guided tour of a distant natural area poses transportation and other difficulties, though it is better than nothing.

The idea for our outdoor laboratory was conceived by Neal Munch, who directs operations in the Freehold Soil Conservation District for the Soil Conservation Service, U. S. Department of Agriculture. With 20 acres comprising the school grounds, there was room for a miniature "natural" area. Our "outdoor classroom" was strategically located between two wings of the school building. Protected on three sides by the building, it was further safeguarded at the open end by a tall, wire fence.

Mr. Munch's idea was to make the outdoor laboratory, or simulated natural area, representative of the whole state. So, our area contains separate segments representing New Jersey's pine barrens, upland areas, meadows, and swamps. Conservation is emphasized in all the settings.

The actual soil and vegetation were brought in from their natural areas. Several of our older students helped with this chore and supervised the operation. Mr. Munch and Harold G. Smith, the general science teacher, handled the transportation. They did the work on their own time, after school and work hours, and on Saturdays. The pupils, in this "bring-in" project, learned something about the different resource areas of their community and state.

The outdoor laboratory was started in the fall of 1962 and it now consists of miniature reproductions of several New Jersey land resource areas, 200 different plants characteristic of the various areas, 28 types of animal life, and two ponds. The source of water for the ponds is roof drainage and an outside faucet. To make them leakproof, the clay bottoms of the ponds were thoroughly tamped.

The turtles, frogs, rabbits, fish, water and land insects, and microscopic life in the laboratory draw the attention of all the students, from kindergarten tots to eighth-grade grownups. Microscopic life, when made visible by magnification, always opens new vistas of knowledge and experience. Other objects of interest are the many birds attracted to the area by feeders and houses built for their exclusive use.

## Living Contributions

Occasionally, impromptu contributions sharpen the interest of the pupils and teachers. The project had hardly begun, for example, when Mr. Munch, in checking a site on a farm for a pond, came across a nest of mallard duck eggs. With legal authority, he brought the eggs into the school where they were hatched. The pupils studied the growth and habits of the young ducks till they were old enough to be released to their wild relatives.

Quail eggs supplied by the New Jersey Division of Fish and Game were hatched in the school. The baby birds were studied until it was time to return them to their natural habitat.

A legally borrowed fawn was brought to the man-made nature area for study. It was kept, much to the interest of the pupils, until the hunting season was over. Then it was returned to a woodland.

A word of caution: When it comes to using live animals and birds, or hatching eggs, it is generally necessary to check with the state game commission to avoid legal problems.

These contributions illustrate how our nature area has ignited the imagination of people and agencies beyond the school's borders. Help comes from many sources.

## Conservation and the Curriculum

The main purpose of the outdoor laboratory is to help in the teaching of conservation and to sharpen the students' interest in all school work. The nature area is tied in most closely with the teaching of science but in many ways it is allied with other subjects. Zoology is involved in studying wildlife, botany in plant study, and social science in land-use studies.

Fifteen classrooms have a view of the "natural" area. Our teachers take advantage of this view to call the attention of their pupils to the natural resources seen through the windows. Just by looking through the windows, they can enjoy the beauty and variety of the plants and animals and observe seasonal changes.

Mr. Smith (eighth-grade science teacher) states that, "Our 'natural' area has a tremendous potential as a teaching tool. It will be used as such to an increasing degree in the future. Already, in its incomplete form, it has enlightened many of the students and extended their horizons. It is surprising how many students do not know even the most common plants. Likewise, it is a surprise to learn how many have never had a close-up view of the animals that inhabit our remaining woods and parks. With this outdoor laboratory, we are overcoming their deficiency. It is encouraging and stimulating to note how eager the students are to learn when they can come in actual contact with the subject. And nothing stimulates and gratifies a teacher more than alert, interested students."

Our outdoor laboratory is to be expanded gradually. Expansion plans include gardens of wild flowers, a collection of New Jersey rocks and minerals, and a weather station. We have already installed a rain gauge as the first facility of the weather station.

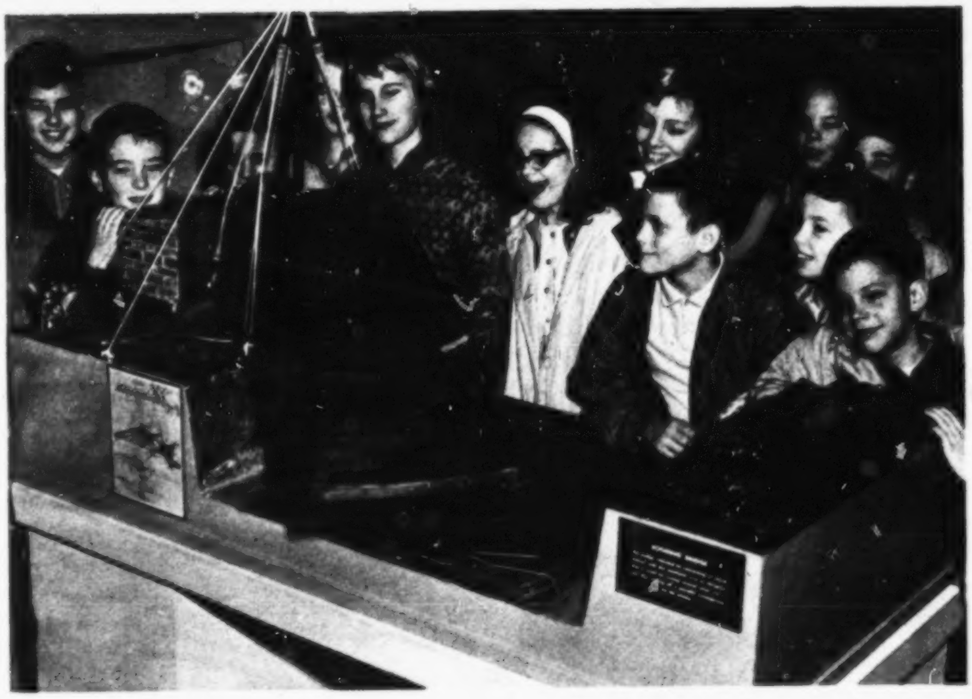
In our outdoor laboratory, science classes learn about the relationship of plants and animals to their environment. The conservation of natural resources is an important part of the general study. Specifics include the study of plants, such as identification of flowers, shrubs, and trees. The pupils study the actual damage inflicted on plants by insects. They use the outdoor laboratory as a source of living things, both plant and animal, for classroom use. Long-range projects are another continuing interest, such as the study of erosion and the rate of plant growth.

Ingenuity and imagination can expand the usefulness of such an outdoor laboratory. For example, Mr. Smith placed a rock under a faucet to show the erosive effect of water dripping on sandstone. The students keep records of the rate at which the dripping water wears a hole in the rock. Now, they can easily understand how rain falling on bare land can wash priceless topsoil from unprotected yards and farms into reservoirs, streams, and harbors.

The natural area involved an actual cash outlay of about $500 which the Freehold Board of Education provided. The largest single item was the fence that enclosed the open end of the area. It cost slightly more than $300. Sand cost about $25 and plants about $30. Most of the sand, however, and many of the plants were obtained free for the digging.

A fence of firethorn encloses the school grounds. While it is outside the miniature, artificial "natural" area, it is used as part of the outdoor laboratory. Its uses are studied, including its service in providing food for wintering wildlife.

In addition to its pedagogic use, the outdoor laboratory has aesthetic values. Together with other features of the school grounds, including the fence of firethorn that blooms in beautiful profusion, it has enhanced the value not only of the school property but of the entire neighborhood.



*Students view a model of one of da Vinci's inventions, the rotating bridge, at the Oregon Museum of Science and Industry.*

# Field Trip Tips

**RAYMOND E. BARRETT**

Director of Education
Oregon Museum of Science and Industry
Portland, Oregon

"The children are getting restless these days! It might be a good idea to have a field trip. Now, where can we go?"

These are phrases too often heard among school teachers. Unfortunately, the attitude expressed is almost certain to doom the resultant trip to an educational failure. Certain considerations must be given to the proper planning, motivation, and results of a field trip to make it worthwhile. A few of these too often slurred-over activities are presented in this article.

## I. Understand the Purpose of a Field Trip

The discipline we call science is filled with the abstract. It is thought of as largely a verbal world composed of complicated ideas and concepts, a foreign language of terms and vocabulary, taught in a whirlpool of constant change. In school science there is too little that a child experiences with his senses. Therefore to give a child more ways to use his senses in studying science, a field trip is necessary. It will provide experiences that will help make real that material which has been presented as a few symbols in a book or as ideas expressed in a discussion. This type of activity is necessary to form a firm foundation or framework upon which to build new ideas and knowledge.

## II. Have a Reason for Taking the Trip

Most teachers have an objective or reason for planning their class work. Yet, some of these same teachers will take a class on a field trip merely "because they need a change." One good objective for a study trip is to awaken curiosity. Vast new areas for possible investigation are opened up when a trip is taken *before* beginning a new unit of study. However, the teacher should be prepared to do something with this newly aroused curiosity when the students return to the classroom.

Taking a field trip *during* a particular unit of study will stimulate more interest in the subject. By then, the students have learned enough to have definite questions and problems in mind, but not so many that the trip becomes a review of what has already been learned. New questions and ideas should arise out of such a trip.

A field trip can also *culminate* a particular unit of learning by clarifying vague ideas and giving students a tangible basis for remembering. Even on a trip of this type, students need to be faced with new ideas and problems which could stimulate additional study at a later date.

## III. Take Field Trips at Appropriate Times Throughout the Year

The field trip should be related to the course of study rather than the season of the year. A heavy burden is placed on museums, zoos, industries, and other institutions normally the object of visits when the spring season arrives. So, a class visiting during a quiet period usually receives a more effective tour from a less harried staff.

### IV. Preview the Potential Lessons

The students need a purpose for learning. Ideally, students should have certain questions in mind when they go on a field trip. Obviously, more questions can be stimulated if the teacher is aware of what her students will see. If possible, the teacher should write for literature in advance so that she and her class will be familiar with the overall operation and scope of the institution to be visited.

### V. Expand Your Learning Experience

On a field trip, nothing is so wasted as the time going to and from the destination. This time can be used to point out interesting features of the countryside. Students can be encouraged to become good observers when they travel. Questions such as these can be posed during the trip:

"What kind of a tree is that? Why is it so much smaller than its neighbor? Does anyone know the name of the building at 11 o'clock? (The front of the bus is considered 12 o'clock, the rear is 6 o'clock.) What caused that dirt bank to slide? How could the slide have been prevented?"

Teachers who use this approach find that their children are busy observing and are ready to learn when they arrive at their destination.

### VI. Tips at a Museum

The teacher must keep in mind that the children come to the museum to look at exhibits. They should enjoy doing so and should leave with the feeling that the experience was interesting and worthwhile, and that the museum is a good place to visit. The function of the guide or teacher is to help children observe, not to teach a lesson or simply deliver a host of facts.

The group should always arrive on time. Often, the staff at a museum has to work out a very close time schedule in order to handle more than one class. Even a 15-minute delay throws off such a schedule.

*Students may see interesting and unusual sights on the trip, such as the results of a windstorm as shown below.*

Teachers should avoid rushing the children into a tour before they have a moment to adjust to the guide and the building. If a common bond is established between the guide and the group at the start, this will set the pace for the trip and eliminate many discipline problems.

(If a guide is supplied, this does not mean that the teacher should settle back with a sigh of relief and relinquish the group completely. The guide is available to help the children learn and to answer their questions. Maintaining discipline is not part of his job.)

A group should never be rushed to a new room or exhibit without explaining the exhibit—orienting to the whole before examining the individual parts. Why not pause outside a room, tell them something about the exhibit to pique their curiosity, and then ask them what they would expect to find?

Sometimes it is necessary for a teacher to be enthusiastic even if she feigns enthusiasm. By starting a tour with exhibits about which a teacher is genuinely enthusiastic and knows well, she will help to stimulate the interest of the students. There are several ways children's attention and interest can be held if a teacher will:

1. stand beside an exhibit while examining it and face the group so that she can command their attention while they observe and discuss;
2. speak briefly at the grade level of the students;
3. pose some questions that they could answer with careful observation;
4. give them time to observe the exhibits independently;
5. be sure that all students in the group can hear the questions and comments; and
6. repeat any questions asked so that all may hear.

The capacity for sustained interest varies from group to group. The pace must be set according to the capacity of each group. Children will examine some exhibits thoroughly, and others only briefly. It is better to pass on to another exhibit than to spend time over one which has failed to arouse the children's interest. Ideally, the children should leave the museum feeling that they have had a good time, but that there is still more to see, and they would like to return.

### VII. After the Trip

The follow-up to a trip is almost as important as the trip itself. If a teacher shows no interest in what the group has seen, she indirectly tells the children that once the trip is over, they can forget the whole experience. The good teacher builds upon the field trip and encourages students to seek answers to the problems posed during the venture. In the words of Albert Einstein, "An inquiring mind is more important than knowledge itself."

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NOTE: A comprehensive guide to all types of field study has been prepared by the National Science Teachers Association in the publication, *Teach Science Through Field Studies* by Paul DeHart Hurd. Copies of this leaflet are available from NSTA, 1201 Sixteenth Street, N.W., Washington, D. C. 20036 for 35¢ each.

# Evaluating Science Books For Children

**HILARY J. DEASON**

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American Association
For the Advancement of Science
Washington, D. C.

Why should elementary science teachers become involved in the process of selecting good science and mathematics books for school and public libraries and in advising parents as to the books they should purchase for their children? The reasons are self-evident in a cursory review of what is happening in the revisions of the educational process.

Many concerned individuals and organized groups have been engaged for the past decade in assessing the traditional teaching methods and curricula in science and mathematics, and in bringing them up to date. Realizing that all responsible members of a literate society need a cultural background in the sciences and mathematics, whatever their trade or profession, some universities and colleges long have offered cultural courses in the sciences for nonscience majors. Such cultural courses usually rely heavily on collateral reading in standard works consisting of biographies, essays, treatises, histories, anthologies, and current reports of working scientists.

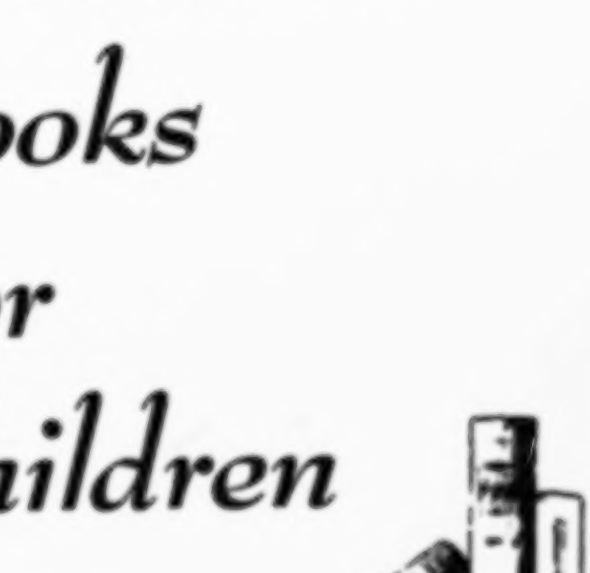
The newer elementary and secondary courses in the sciences and mathematics being developed through the *collaboration of working scientists*, college faculty members, and elementary and secondary school teachers are based on the same fundamental objective: Science, including mathematics, is a part of all life and culture. Therefore, fundamental scientific literacy must be part of the sum total of knowledge of every person. In other words, the basic science courses in elementary and secondary schools are for all students—not merely for those who have vocational goals in science and technology. The objectives of the recent approaches to science education place emphasis on the broad, dynamic principles, laws, and processes which often lead to no final answers, but contribute segments of a gradually developing body of knowledge. Science, then, is a continuous expansion of an incomplete body of knowledge.

The AAAS Commission on Science Education, for example, in its new elementary science curriculum for grades 1 to 6, now being tested and evaluated, takes a multidisciplinary approach with the objectives of teaching the following elements: recognizing space-time relations; recognizing number relations; observing; classifying; measuring; communicating; inferring; predicting. Groundwork is being laid for the all-important task of education—teaching a student to do his own thinking.

Modern science and mathematics curricula necessarily must rely heavily on collateral reading as well as involve the student in meaningful individual science experiences. Such reading provides breadth and depth to the knowledge obtained from the textbook and laboratory exercises. It enables the reader to understand more clearly broad applications, implications, and future possibilities for the skills and techniques he has learned. Since "science is the servant of man," according to I. Bernard Cohen, the reader can understand best how it has served in the past, how it is serving in the present, and how it may serve in the future through collateral reading and thinking.

An analysis of elementary school library collections as well as children's departments in public libraries indicates a deficiency in science and mathematics books (averaging 10.2 percent in school libraries in contrast to the recommended 25 percent). Too many of the science books are out of date and poorly chosen. Frequently, budgets for the purchase of new books are unrealistic or not available.

The traveling libraries administered by the AAAS from 1959 through 1964 demonstrated that children will read liberally and voluntarily if they are presented with interesting and challenging material, and many of them have an appetite for books marked by publishers



as suitable for older age groups. Initially and upon receipt of the traveling collections, many librarians wrote that the books were "too hard" for most of the children and that they needed easier books. They were requested to wait and observe the reactions of their young readers. Many responded a second time indicating that their first appraisals of the books in relation to the reading ability of the students were in error, for "all the books are out." As children, and many of their teachers, became acquainted with authentic and inspiring books for the first time, there was growing interest and improvement in reading on the part of the "reluctant" and "slow" readers. Reading appropriate books stimulated interest in individual science projects.

Good collections of science and mathematics books are indispensable in all school, college, public, and home libraries. Reading for students should be chosen as "occupational reading." Reading is the *occupation* of students and they are paid for their work in terms of knowledge, ability to think, and increasing personal skills. Selection of science books, either for the home library or for school or public libraries, should be based on the same standards.

Books for children and young adults, however, are difficult for the layman to evaluate. The following general suggestions, based on criteria used in the evaluation of books for *The AAAS Science Book List for Children* and the new AAAS publication, *Science Books: A Quarterly Review,* may be helpful:

### Authorship—

Who is the author? Do his education and experience qualify him to write a book on this subject?

### Subject and Content—

Is the subject one of fundamental interest and importance to the prospective reader? Is the subject handled in sufficient depth so that it will constitute a worthwhile learning experience for the reader? Is the organization logical in sequence of ideas and details? If the book answers the fundamental questions of "how" and "why" using appropriate technical terms, it probably is a worthwhile purchase. If it is a superficial survey covering too broad a scope, perhaps it should be avoided.

### Illustrations—

If the photographs and drawings are accurate, are accompanied by adequate explanatory legends, and are directly keyed to the text, they serve a useful purpose. Mere embellishments that add nothing to the text, but add to the cost of the book, are seldom worthwhile.

### Vocabulary—

Most young children converse freely and intelligently with adults, acquire a broad vocabulary through radio and television, and hence can and should read any words that are the best choice for expressing scientific ideas and concepts. "Controlled vocabularies" for children's books are totally unnecessary, and are being discarded by many authors who formerly adhered to them. With pronunciation markings, and definitions either in the text or in a glossary, a reader of any age can understand and learn to use correct technical terms.

### Biographies—

Science biographies for children and young people should be written as contributions to the history of science and therefore stress the biographee's discoveries, contributions, and professional attainments and associations. A fictionalized biography that relies heavily on manufactured conversation and relates nonessential personal details may be interesting reading, but has no value in science education.

### Nature Study Versus Science—

Animal tales and folklore have their important place in children's literature, particularly for preschoolers. When they begin school, children deserve more substantial fare—no talking animals, no anthropomorphisms, no "Dick and Jane" reading matter. Superficial nature study ("look and see") never was very exciting to most children. The same material taught in terms of biological science (Who? How? Why?) is interesting and enables students to "get involved." Buy genuine biology books for children in preference to superficially descriptive and sentimentally written "nature books." Look for books that give complete life histories or ecological studies.

### Physical Science and Technology—

Merely descriptive books about rockets, missiles, airplanes, atomic reactors will entertain but are not educationally worthwhile unless they introduce the reader to fundamental scientific laws and principles—and to the painstaking underlying research and experimentation. Such books should demonstrate to the reader how and why his science and mathematics courses are basic preparation for those who want to be scientists, technologists, doctors, engineers, and space travelers.

### Experiment Books—

"Doing things" and "making things" are essential activities for all children. If "experiment books" are designed to demonstrate scientific facts and principles, encourage the reader to do additional experimentation on his own initiative, and stress the value of additional background reading, they are good purchases.

### Reaching Upward and Outward—

In selecting reading for children and young people, it is well to buy books that they will have to "grow into"—books that hold their interest but require repeated reading and study to understand and enjoy thoroughly. Books should be chosen not only to deepen the reader's major fields of interest, but to acquaint him with other, unfamiliar areas of knowledge. High school students report frequently that their good scores on the Scholastic Aptitude Tests have been made possible by their varied and liberal voluntary reading habits that date back to grade school days. Career choices are made, frequently, on the basis of background acquired through collateral reading which has expanded the readers' knowledge to fields not explored completely in the classroom lesson.

The application of the foregoing selection criteria results in the rejection of many so-called children's science books produced by free-lance writers who lack sound scientific training or who handle facts carelessly. Professional science writers, scientists, and science educators are the best-qualified authors of good science books. The new elementary science curricula that are being prepared and evaluated will begin to emerge as commercially published teacher's manuals within a year or so. There is an urgent immediate need for the writing and publication of children's books produced in the same spirit and dynamic concepts of the curriculum materials. It is hoped that more people with good scientific backgrounds will study the new curriculum materials and put their imagination and ingenuity to work in the production of children's science books that are needed for collateral and recreational reading by children. The market for children's science books has been greatly increased through the financial assistance available through the National Defense Education Act and the Library Services Act. Other legislation providing federal aid to education, when enactment and implementation are completed, will further magnify the potential market.

# Equipment a la "Cart"

**CHRYS SCHROEDER**

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Pershing Elementary School
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The science club of Pershing Elementary School has served to upgrade the science program of the entire school through one of its activities. The club, organized by students from the fourth through sixth grades, performs a service by maintaining an inventory of all science equipment and a record of the whereabouts of each item.

When the club began, the initial duty was to take an inventory of all science equipment which had been issued to the elementary department and to assign a designated place for each article. The article was then marked and cataloged in such a manner that any piece of equipment could be checked out or in by any club member as the need arose.

The membership of the organization is composed of two representatives from each of the seven classrooms. These fourteen students serve as student helpers whose duties are rotated periodically to enable each member to gain experience in handling all aspects of the service.

Each morning, a designated member of the group contacts all the elementary and junior high school teachers to determine what science equipment will be needed for the day. The member then sees to it that the requesting teacher has his material on time. Whenever necessary, groups of helpers pick up and deliver equipment, as shown in the photograph. Carts are used to transport the items to the various rooms. When a teacher is through with equipment, he advises the club member who then returns the material to its assigned location in the storage area. This operation has expedited the use of the science equipment available in the school and has given teachers additional time to devote to the planning of the science lesson.

With this integrated plan for sharing equipment, a more efficient and complete science program has been carried on. Also, because of the close proximity of science club sponsors in both the elementary and junior high school, our science program encourages cooperation to make the transition from elementary to junior high science a normal and natural procedure.

# Rewriting Science Materials For Elementary Students

**R. C. BRADLEY and N. WESLEY EARP**

Department of Education and Psychology
North Texas State University
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ELEMENTARY science teachers depend in large measure on science textbook series for the subject matter and the activities to be presented. One disadvantage to this standard practice is that current information in science may not find its way into the elementary school curriculum. Space exploration is only one significant example of the rapidity of new developments in science. Discoveries about animal and plant life also offer continuous sources of information and interest to children.

The elementary educator can bridge the gap between what is presented in the science textbook and the recent developments in science by reading and rewriting up-to-date science material. Certain science periodicals, such as *Scientific American*, present informative articles concerning the latest developments in science. Because this material is written on an adult level, it is most desirable that qualified persons select and rewrite the articles at a lower reading level so that children may have the actual experience of reading new information for themselves.

## Guidelines for Rewriting Material

This article offers guidelines for teachers interested in rewriting current scientific materials. A recent experimental study conducted by the authors revealed that children who read rewritten articles scored significantly higher on tests covering the data than did those who had articles read to them or attempted to read difficult articles for themselves.

From our experimental project and experiences with rewriting work for elementary children in a classroom situation, we offer the following guidelines for consideration by supervisors, principals, or teachers who undertake the practice of modifying scientific articles for children.

### 1. Use Care in Article Selection.

Select the articles to be modified with great care. The article selection varies according to the use you wish to make of it: (1) as a supplement to a lesson, (2) as a separate presentation for class work at a time other than the science period, or (3) as a self-contained lesson to be learned. In any case, specialized competencies (higher mathematics, knowledge of chemistry, technical vocabulary) on the part of the child, although desirable, should not be necessary for him to understand the meaning of the rewritten article.

### 2. Keep Writing Style Simple.

Write clearly and simply, using words appropriate to the intended grade level. For children one writes to communicate, not to impress.

### 3. Relate Subject to Child's Environment and Development Level.

Freely use the techniques of comparing, contrasting, and developing examples and statements analogous to the child's experience and environment. Some knowledge of child growth and development is mandatory on the part of the editing official. For this reason, it would be good if teachers of a given grade level provided their own rewrites of science articles for classroom use. They would be fully aware of vocabulary level, attention span, and the unique interests of their own group.

### 4. Use Graphs and Charts.

If at all possible, organize some data into simple graph or table form. Children at the elementary level need to become familiar with graph and chart reading. Often, simple cut-outs from construction paper of various colors will make a difficult idea easily comprehensible for the young child.

### 5. Limit Details.

Avoid setting out to answer specific questions. Write in a style that lets the information unfold in such a way that it can be readily grasped by the pupil. Children generally get "bogged down" in extraneous details.

### 6. Be Consistent in Use of Grammar.

One should employ consistent uses and notations in rewriting an article. Italics can be used to show the use of technical terms or for emphasis. Parentheses might enclose the pronunciation of a strange scientific word, a definition, or an explanation. Abbreviations should be used with utmost care.

### 7. Check Your Rewrite for Accuracy.

Have another informed person read both the original and modified article for accuracy in fact and interpretation. In all cases, give proper credit and concise bibliographical reference to any material that is rewritten.

### 8. Use Testing to Determine Effectiveness.

Prepare a brief but thorough test (preferably multiple choice) that calls for the child to reflect on what has been studied. On some occasions it would be well if a pre- and post-test evaluation were conducted to check on individual student achievement and improvement.

## Concept and Vocabulary Control

Articles chosen for rewriting should be chosen for specific purposes. For example, an article entitled, "How Reptiles Regulate Their Body Temperature,"[1] can be rewritten to refute the contention of many science books that reptiles—as coldblooded creatures—take on the temperature of the surrounding air. In this case, the inclusion of every distinct concept is not necessary—only those concepts necessary and essential to the meaning of the article.

The following excerpt is from the original form of the aforementioned article:

> Whip-tailed and spiny lizards often occur side by side in the same habitat. *Invariably* they show an average difference of 10 or 12 degrees between the means of their *respective* ranges in temperature, even though the identical sources of external heat are available to both. This alone is evidence of the *effectiveness* of *behavioral* control of heat intake and *dissipation*, *augmented* by *pigmentation* and *enhanced* by *adaptation* in structure.[2]

The italicized words are those believed likely to present difficulty to children at fifth- or sixth-grade levels. None of the words in italics are found to be frequently used by writers who write for juveniles, according to Thorndike.[3] The Thorndike list and vocabulary lists of a basal reader series indicate that the other words, such as degree, temperature, or evidence, can be used. In most instances the names of animals, things, and processes should be retained. The authors have rewritten this article exercising concept and vocabulary control. The rewritten selection follows:

> Whip-tailed lizards and spiny lizards often live in the same places. These reptiles have the same things to keep them warm or make them cold. It may seem strange then that the *average* body *temperature* for whip-tailed lizards is about 10 to 12 degrees higher than that of the spiny lizard. This is *evidence* that these two groups of lizards act *differently* in the way they use the aids they have to keep them warm. A lizard can help his temperature to stay near the same level by the way he breathes and by changing color to *absorb* more of the heat of the sun. He may also choose a place to *bask* to warm him, or seek a shady place to cool off. In fact, the way he lies in the sun changes his temperature. Using these *means*, the whip-tailed lizard acts in ways that keep his temperature at his preferred level. The spiny lizard does not like it so warm; and though he uses these same aids, he keeps himself cooler.

The words in the rewritten paragraph are either comprehensible to fifth and sixth graders or are nouns which cannot be changed. The italicized words were all carefully checked and found to occur quite frequently in juvenile literature according to Thorndike. Most of them are also to be found in the vocabulary lists of fifth- and sixth-grade basal readers. Another interesting source to check children's comprehension is in Gates.[4] According to the Gates' list all except one of the italicized words in the rewritten passage are intelligible by at least 70 percent of fifth graders.

As change occurs in our society, the presently available word lists become more dated. However, this is one reason that the use of basal reader word lists is mentioned. Such lists will continue to be updated frequently and represent expert opinion on words children are able to comprehend.

Above all, the judgment of the "rewriter" is of great importance. This person must know children, be in constant touch with them, and have a realistic view of their comprehension level and linguistic progress.

## Reading Aloud Is Not an Effective Substitute

Too often children have had scientific material read to them that they could not have read themselves. Research shows that simply reading something aloud will not assure one that what is being read is within the understanding and capabilities of the child. Materials selected to be read orally to children must be pitched below the level at which the child reads, because this is the only way for him to recognize or cope with his speed of listening. One must recognize that as the child reads silently, he adjusts himself to his own rate of understanding. However, as the teacher reads orally, he sets the pace for the child's thinking; and it very well could be that words and concepts are either vague or unrecognized. Moreover, the child cannot keep up mentally with the ideas if the oral reader does not pace himself to the child.

The aforementioned facts present a sound basis for the encouragement of educators to rewrite certain selected articles coming from quality materials in science for purposes of: (1) extending and supplementing regular textbook materials, (2) updating the text by refuting a statement or by pointing out new scientific discoveries, and (3) providing simplified materials for either the child's silent reading or for group reading by the teacher.

Anyone who rewrites material must bear in mind the danger of mistaking shorter, less complex words or expressions for easier meanings. Scientific words are difficult or easy to a child not only in proportion to the incidence of their general use, but also for the association or experience the child has had with the scientific concept for which the words stand. Scientific *words* are not necessarily difficult to children; scientific *ideas* are.

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[1] Charles M. Bogert. "How Reptiles Regulate Their Body Temperature." *Scientific American*, April 1959, p. 105.

[2] *Ibid.*, p. 112.

[3] E. L. Thorndike and Irving Lorge. *The Teacher's Word List of 30,000 Words*. Bureau of Publications, Teachers College, Columbia University, New York. 1944.

[4] A. I. Gates. *A List of Spelling Difficulties in 3876 Words*. Bureau of Publications, Teachers College, Columbia University, New York. 1937.

# Editorial . . .

This is the time of the year when elementary school principals and teachers consider ordering science equipment and supplementary books. Many of these materials will be purchased with matching funds obtained from the federal government under provisions of the National Defense Education Act (NDEA). Tons of science equipment and books have arrived in our schools since the Act became effective in 1958.

## Seven Years of Purchases

After seven years of such purchases, schools often find that they are glutted with more test tubes and racks than can be used profitably for the next ten years. Elementary educators have long been seeking easy solutions to this problem of purchasing the necessary science equipment. Busy administrators, duty-laden science chairmen, or inexperienced teachers have ordered expensive commercial kits as a "way out." But, do you really need all of the component parts of a large expensive kit? Would not several small expenditures of permanent items be more helpful for the school science program? Perhaps this is the time to think in terms of purchasing one big expensive piece of science equipment in lieu of several small purchases.

We should ask ourselves the following questions: (1) Have our purchases been based on sound science curriculum planning for grades K-12? (2) Have they been hit or miss purchases which are not based on any curriculum structure? (3) If we do have a K-12 curriculum, is it evaluated regularly to make any necessary changes and additions? (4) Is the equipment we buy helpful in filling a gap or need in our program? Many times we purchase equipment and then try to think of ways we can use it in our programs. Each item purchased should be within the scope and understanding of the elementary teacher and child. Equipment of an extremely complex nature is of little or no value in the elementary school.

NDEA has been part of the educational scene long enough for educators and others interested in science education to set some standards for equipment which will be useful in the elementary school. This has been done by the Council of Chief State School Officers. See the article in this issue on page 7 by Leo Schubert. It should be made clear, however, that publications, like materials, can only serve a purpose if they are read and used.

## What Should Be Done?

Once the equipment arrives at the school, other administrative problems begin. Have plans been made for the storage, organization, and distribution of the material? In order to be used effectively, the equipment has to be readily available and in good repair. The March issue of *Science and Children* contained many good articles on how to establish, maintain, and use a science resource center. Are in-service programs planned to assist the teacher in the proper utilization of the new materials and equipment? Too often science equipment just lays on a shelf gathering dust, or in some unpacked carton. In many cases it is because teachers have not had the opportunity to become familiar with the equipment and how to use it effectively in the classroom. Sometimes the teacher does not even know what science equipment is in the building. A real effort needs to be made to help teachers become familiar with the proper use of science equipment.

Elementary school science education will undoubtedly continue to improve with the addition of all this new equipment. But, the degree of improvement depends upon the thoughtful consideration given to the selection, storage, and use of these materials.

MARJORIE S. LERNER
*Principal*
*G. T. Donoghue Elementary School*
*Chicago, Illinois*

LOUISE RITSEMA
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*Ann Arbor, Michigan*

# SCIENCE EQUIPMENT STORAGE

**WILLIAM J. WALSH**

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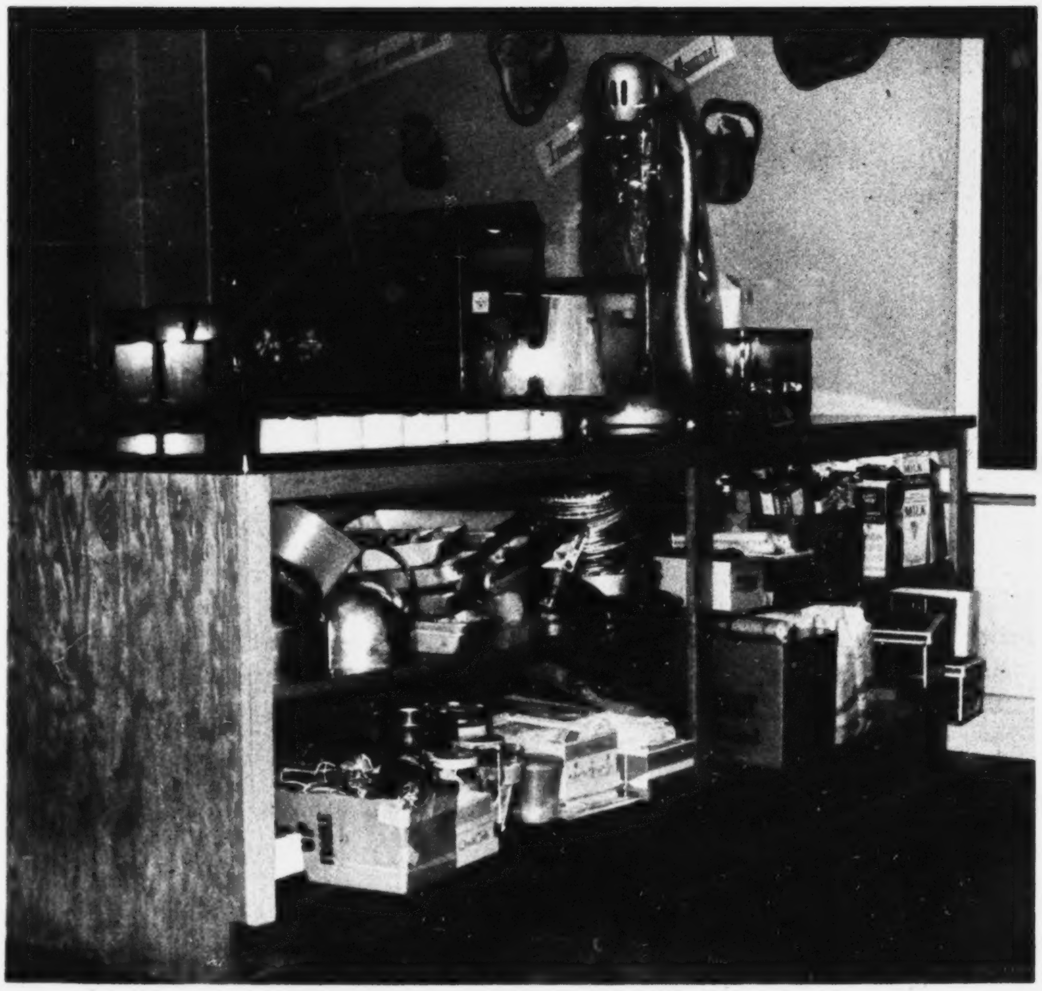
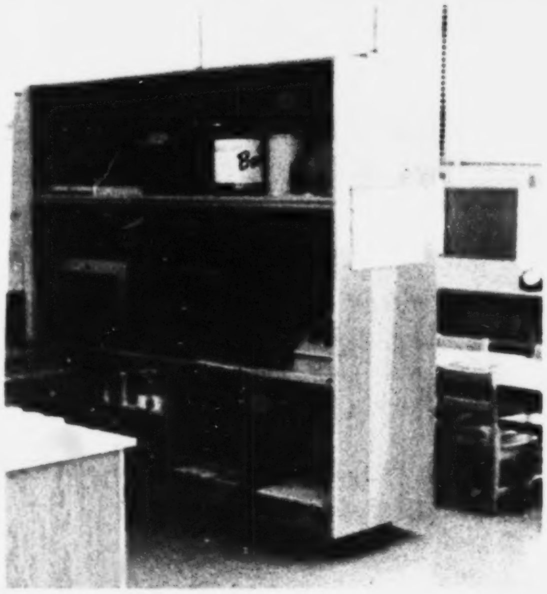
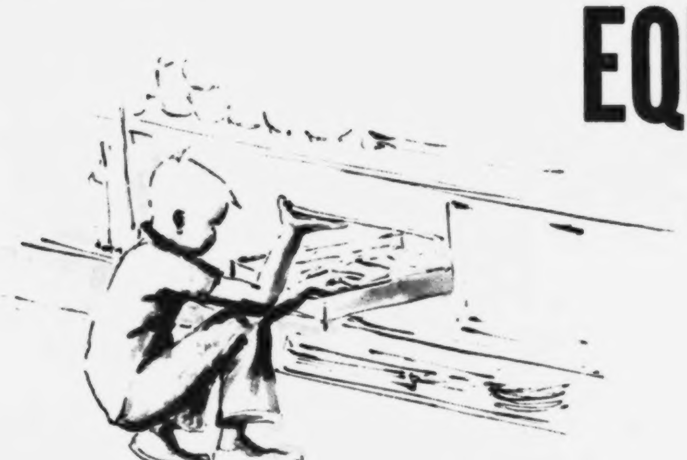




*In addition to scientific equipment purchased from a science supply house, the science storage center should contain materials that can be found in the students' homes (above). With adequate space available, the storage of animal cages does not present any problem in this science materials center (left).*



Few teachers would question the need for a continuous improvement of science instruction in the elementary school. Accompanying the demand for quality instruction is the need for more science equipment. With financial encouragement from local resources and the entitlement features of state and federal agencies (National Defense Education Act), it is obvious that more equipment is being purchased for use by the teacher in developing the elementary science curriculum.

Yet, these encouraging developments are not paralleled by similar advancements in centralizing equipment and supplies and making them readily available to all teachers of the elementary school. Orders for equipment, which is seldom used or which duplicates available items, indicate that steps should be taken to render maximum service to the school program of diverse needs as well as quality supply in selected areas.

Few school systems can financially afford to provide the maximum amount of science equipment desired in each self-contained classroom of the elementary school. The requirements of storage alone poses a serious problem to the classroom teacher. Moreover, as the program moves from sole teacher-demonstration emphasis to laboratory-type student project approach, a wider range of equipment needs becomes more evident.

Obviously, it is not an either/or proposition. Each teacher is entitled to minimum or basic science equipment in the individual room. Often this is confined to a box or a drawer. It generally includes some simple tools, wire, tape, a source of heat, assorted pieces of glassware, a dry cell, and perhaps a few clamps. As the teacher moves to new units of investigation with the multitude of activities now associated with them, there is a need for specific equipment. Activities for a weather unit, for example, often include equipment requirements for a barometer, also soda straws, nylon thread, petri dishes, metersticks, and assorted pieces of glassware. In most instances, the availability of equipment such as this will affect the planning, execution, and (probably) the success of the unit. But, how can such requirements be met in the self-contained classroom?

Before World War II, many schools depended upon teachers' pocketbooks for supplying scientific equipment. In recent years, however, this arrangement has moved beyond the pocketbook and memory of most teachers, and school systems are providing funds for science equipment at the elementary level. The complexity of school operations and increased enrollments of students has pointed to the need for the establishment of a central facility for the storing of major items of science equipment and supplies.

In some large school systems, a central budget or purchasing office has been established to centralize inventory and purchase science equipment. In other school arrangements, forms of teaching in departmentalized fashion have eased individual teacher requests. Systems which feature the self-contained classroom, however, have not been able to meet student and teacher demands in an adequate fashion without centralizing a common supply of science equipment somewhere in the building. The development of a teacher-planned central storage facility for science equipment and supplies would assist the development of an improved elementary school science curriculum.

### Cooperative Planning

Any centralized facility must be developed by and for the teachers it will service. The physical location must be decided as must be the manner in which it will be used. The wishes of all members of the staff must be considered in initial planning as well as in future development. Some teachers will hesitate to endorse and support the initial plans unless they are assured that equipment contributed to the centralized storage area will be available when they need it. Other individuals who have successfully leaned upon incidental teaching-motivation will be wary of changing habitual preparation patterns. Such common and understandable questions of philosophy and practice should be answered before the move to centralized storage is taken in final form.

### Central Location

A convenient and centrally located space can be found in most schools for centralized science storage. Because of the hourly need for check-out and return of equipment, a large closet is preferable to a corner of the principal's office. For the same reason, a corner of the boiler room, properly outfitted, will be used more advantageously than a corner of a single classroom. Some schools start with a movable supply center such as a large cabinet by which, upon rolling it from one location to another, a site of maximum convenience can be determined. Small schools can begin with the storage afforded by a portable demonstration table. Its limited space, however, often requires augmentation from other storage areas.

### Identification and Classification

Whether a school uses a large bookcase or a series of shoe boxes, the central storage area should be divided into sections that are easily identified and located. This process

*This science materials center has enough room for storage of equipment and space to conduct individual and/or class science projects.*

is often the most difficult to accomplish. Some systems use one box or space for magnets, another for electricity. It is not uncommon to see common teaching units or concepts used as segments of the total classification. For example, a unit or box labeled "Heat" will include thermometers, expansion strips, conduction bars, etc.

Whatever method is used for classification, it should be used consistently. Keep it simple for maximum utilization. In some instances, a simple alphabetical listing might suffice in the beginning stages with permanent groupings selected at a later date.

Physical grouping of the material into boxes, trays, drawers, or other containers is desirable. Commercial storage cabinets with removable drawers or trays lend themselves handily to the science storage area. Carrying boxes with handles as well as wheeled carts will augment the transportation of equipment.

Wherever possible, separate the chemical supplies from other equipment. This will prevent the formation of corrosion and subsequent deterioration of valuable instruments and metal equipment.

### Provide for Expansion

The contents of the original centralized storage area of the school will in most cases result from a pooling of the equipment and supplies formerly divided between each of the elementary classrooms. In terms of future needs, the original collection will probably occupy less than one-third of the space that may be required after a five- to seven-year growth period.

Some schools have discovered corners or blind hall ends which serve nicely as storerooms by "boxing-in" with wallboard or plywood. If remodeling or new space such as this is contemplated, triple the space now needed to provide for future needs.

Bulk purchases of both equipment and supplies will conserve future budgets, but does demand present storage space. A year's supply of glassware or dry cells for a ten- to twelve-room school is not an expensive package but necessitates space that makes these materials available over an extended period of time.

### Inventory Needs

Often overlooked in planning storage facilities, is a means of determining what is stocked in the storage area and when to replace or reorder existing items. This procedure is particularly critical with supplies. A simple card system can be used to indicate, for example, how many ounces or containers of iron filings are in stock. When a classroom teacher or an appointed checker notes the supply is dwindling, a note on an order list should suffice. If the third-grade teacher needs more centigrade thermometers, she should be able to record her request on a list or sheet in the storage room. Planning for the future rests heavily upon anticipating the needs of the individual class as well as the total school.

With an important link in the total science program resting upon inventory, it is helpful for teachers to rotate or share responsibility for ordering and replacing present equipment and supplies as well as processing requests for additional stocks. Where possible, honorary or paid high school student assistance should be considered.

*By checking the file, this teacher can tell what equipment is in the storage area or where it can be located.*

### Fitting Facilities To the Program

The development of central storage facilities should go far to aid the implementation of a desirable science education program. The availability of equipment and supplies should encourage an upward revision of former goals and objectives associated with the curricula. In no instances should the availability or unavailability of an item dictate teaching aims. The knowledge that microscopes are available should encourage the teacher to plan an improved unit on micro-organisms. The presence of the instruments should not in itself trigger a study of the microscope merely as an exercise or busy work.

Many schools work cooperatively with teachers of science at the junior and senior high school levels in securing and developing specific materials that can be used advantageously by all grade levels. Decisions concerned with adding to present equipment should be made in the light of future as well as present needs of the total kindergarten through twelfth-grade curriculum. The possibility of the development of a school or community museum would have serious implications upon the biological specimens, charts, and models contemplated for a system where museum facilities had not previously been available.

The degree of centralization can be overdone. Narrowing the center to a total school system has less promise than centers in individual buildings. Problems of use and return multiply when facilities outside of the building are developed. The test of the degree to which centralization can be made includes the responsibility for providing the maximum utilization of all school facilities. If the teacher loses touch with the program through unnecessary complications, the additional facilities will not be of material benefit to anyone.

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# A Guide To Science Handbook Preparation

WITHIN the past few years, a number of projects have been started to develop science programs for elementary schools. These projects will undoubtedly make important contributions to science instruction in the elementary grades. However, the total impact of a particular program will depend upon the extent to which teachers can put the program into practice in their own classrooms.

To help teachers introduce and use new programs, handbooks have been found to be very effective. Here is a checklist that can serve as a guide to either the preparation or evaluation of teacher handbooks.

1. Are the basic objectives of the science program clearly defined? ☐
2. Are the anticipated outcomes of the science program set forth in terms of specific understandings, attitudes, knowledge, and skills that children may be expected to acquire? ☐
3. Have the science content areas to be explored in the handbook been designated? ☐
4. Has a course of study outline been prepared to serve as a framework for the development of the selected science areas? ☐
5. Does the outline indicate the scope of the material for each grade and the sequence to be followed? ☐
6. Is the material organized in the form of major problems, sub-problems, fundamental questions, experiments and investigations, and understandings? ☐
7. Is the material designed to place teaching emphasis on the purposes, the methods, the processes and the techniques of science, rather than on the mere facts of science? ☐
8. Has an editorial policy been formulated to assure a good format and a concise, interesting writing style? ☐
9. Has an editorial policy been formulated to guard against the use of dogmatic statements? ☐
10. Has an editorial policy been formulated to avoid the temptation to arrive at generalizations on the basis of insufficient evidence? ☐ Are such words as every, all, never carefully checked to make sure that they can be justified in a statement? ☐
11. Has an editorial policy been formulated to avoid the perpetuation of unverified anecdotes about scientists or their discoveries? ☐
12. Has an editorial policy been formulated to guard against the inclusion of anthropomorphic statements which attribute human attitudes and feelings to plants, animals, or inorganic things? ☐
13. Are the teachers introduced to the great variety of approaches and techniques that can be used in science instruction? ☐
14. Are the problems and questions at each grade level of interest to and within the scope of the understanding of the children at each level? ☐
15. Do the questions serve to provoke thought and stimulate activity? ☐
16. Are the questions of such a nature that children may be expected to obtain answers to them with some degree of success? ☐
17. Do the questions, explorations, and experiments encourage the children to think things through on their own power? ☐
18. In the development of activities, are the children trained to devise their own approaches and materials, to be on the lookout for ramifications of the original problems, to strike out in new directions, and to come up with a variety of findings? ☐
19. Are the activities presented in such a way as to leave the door open to unexpected discoveries? ☐
20. For each activity, are the expected learnings set forth in clear, simple terms? ☐
21. For each area, are enrichment activities suggested for children who may wish to explore the area in greater depth? ☐ Are leads to project work and further experimentation provided? ☐
22. Are the illustrations clear, accurate, and to the point? ☐ Do they contribute to a better understanding of the text? ☐
23. Are the supplies needed for the activities safe to use and easy to obtain? ☐
24. In each area, is adequate and accurate background material presented to enable the teachers to guide the work in the area with confidence and with some degree of comprehension? ☐
25. Does the handbook contain up-to-date bibliographies of reference books for teachers and science books for children? ☐
26. Does the handbook contain lists of appropriate audio-visual aids? ☐
27. Is reference made to community resources that might prove of value in the study of particular science areas? ☐
28. Does the handbook contain a glossary of science terms? ☐
29. Does the handbook have a table of contents and an index? ☐
30. Are the supplies needed for the activities in the handbook summarized in a special listing? ☐
31. Does the handbook feature an appendix of useful facts and measurements? ☐

The Science Materials Center provides opportunities for students to work in the fields of

astronomy . . .

microscopic life . .

# Beginning A Science Center

**NORMA L. NELSON**

Resource Teacher
Meadow Hall School
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In recent years, more elementary schools have begun to develop science centers. Local instructional funds have been used to purchase science materials for a central location rather than scattering equipment throughout the building. In many cases, supplementary monies under Title III of the NDEA have also been available to bolster the local allotment.

After considerable discussion by administrative and supervisory staff from the Montgomery County Schools, it was decided that the Meadow Hall School in Rockville, Maryland, would house the County's first science center. This decision marked the beginning of an extensive "How-to-Do-It-Project" for developing a science center. The project involved ordering equipment, planning the center, arranging for the actual use of the center, and carrying on a continuous evaluation of the center and its operation.

The first step was to get the equipment ordered within the time allotted. To do this, the goals of the science program were reviewed. Catalogs and brochures were scanned to discover the kind of equipment available. Teachers listed the materials which they thought would help them in their teaching of science. Available space, current inventory of materials, and possible use of equipment by elementary children were all considered before the final order was submitted for approval. All the major areas of the science curriculum were studied by the supervisory staff to insure that there was a balanced distribution of materials for all areas of study.

The next phase was to plan the actual physical set up of the center. A regular elementary classroom was made available and was renovated during the summer. The floor plan, designed by a faculty member, kept in mind the needs and habits of elementary children, as well as needed storage space and work areas.

The work areas planned were:

1. *An animal area* placed in the corner of the room where a sink was already available. Shelves, drawer space, and a movable rack were included to provide room for aquariums, cages, animal food, and other necessary supplies.

2. *A plant area* was designed near the windows. One window pane was removed and a small greenhouse was constructed. The greenhouse was enclosed with plastic, and was heated as necessary with an electric light bulb. Bookshelves were converted into cupboard space for flower pots, potting soil, and other related equipment.

3. *A demonstration area,* covered with Formica, was designed in a large U-shape to give maximum

ANIMAL KING

weather . . .

plants . . . and

living things.

viewing space. Drawers, shelves, and cupboards were built underneath the demonstration table for additional storage.

4. *A weather study area* was placed near the windows. Hooks were provided to display the weather instruments, and existing bulletin boards were left to exhibit weather maps and cloud charts.

5. *A reference area* was planned for use by both children and teachers. Reading tables of the sizes needed by both primary- and upper-grade elementary children were moved into the room and many single copies of science books on various levels were gathered here. Some groups of five to ten books of one title and science references were also included. Directions for the use and operation of the equipment were filed in this area, as well as sample science units. Picture collections were begun for the various areas of science, and a biographical file of famous scientists was started. A resource file was made available, which listed prospective field trips and community residents, from doctors to electricians, who were willing to speak to interested groups. This area also housed the check-out card file which listed where the science equipment was being used or stored. Pictures of the various pieces of equipment were cut from science supply catalogs and pasted on the backs of the cards to help familiarize both teacher and child with the name and appearance of the item. A brief yearly outline of the school's science program was posted in this area along with a weekly schedule for use of the center.

6. *A storage area* was devised from the existing coatroom. One of the coatroom doors was closed to make a glassed-in display case. Inside the coatroom, shelves and pegboards were provided to store such large items as bell jars, garden tools, and buckets. Scraps of wood, pieces of plastic, nails, wire, and other materials were also stored here.

In the fall, it took several weeks of unpacking, inventorying, labeling, and arranging before the next phase of the center's development could begin. After the center was established and ready for use, the entire school faculty met there to become familiar with it and to help plan maximum use of it. At this time, a schedule was set up to bring each class, beginning with the older groups, to the center for an introductory lesson. During these introductions, the areas were pointed out and new equipment was briefly demonstrated. Goals, standards, and suggested uses of the center were discussed with the children at their various grade levels.

### Student-Parent Contributions

After all the children had visited the center, plans were made to begin collecting supplementary materials which would enhance the science program but for which monies were not available. A suggested list of such materials went home with the children. The response was tremendous and the center was not quite ready for the deluge of materials that this request brought forth. The yield from this collection phase ran the gamut from live turtles to a stuffed great horned owl; from candles to old electric appliances; and such treasures as a bottle of volcanic ashes from Hawaii, to a worn, but prized, chipmunk skin.

By the first of October, the science center was ready for actual use. Teachers had met at several workshops to work out demonstration-experiments, to learn how to use such equipment as the microprojector, and to set up further plans for the use of the center.

These plans included having the room available for the following uses:

1. For the teacher to bring his own class there to teach his own science lesson.

2. For a small group to come to work on a common problem.
4. For a central location of science equipment which could be used in the classroom.
5. For an area suitable for in-service science workshops and demonstration lessons.

These uses made it necessary to have a teacher present in the science center as much as possible. Arrangements were made to release one teacher from an assigned group of children so that the needed instruction could be provided in the center on a half-day basis. Children were scheduled to come in small groups or as individuals during this half of the day. The other part of the day was available for teachers to bring their groups to the center.

### Student Leaders

Several older science-interested children were trained to conduct "tours" of the center for small groups since collections such as rocks, shells, or plants were continually changing. Another such group was trained to assume the inventory and housekeeping tasks of the center.

Evaluation procedures were carried on throughout the year. Records were kept of the use of the equipment in an effort to help guide future purchases. The kinds of experiments performed and projects completed were also tabulated. Teacher workshops were held during the year to provide continuing growth in the use of new equipment and to keep the teachers aware of the new developments in the area of elementary school science education. Schedules were studied and many revisions took place during the center's first year of operation.

Several observations were made as a result of the evaluations:

1. Extremely high interest in the science center has been shown by the majority of elementary children.
2. Girls were slower to become involved with individual science projects, but by the mid-term as many girls as boys were taking part in the program of individual science activities.
3. The trend of student investigations seemed to be toward the natural sciences rather than the physical sciences.
4. Children and teachers seem to be more familiar with science equipment, both in the actual handling of the material and using the proper terminology.

The information gained in the first year of operation of the science center should prove to be valuable in planning for better use of the center next year. It will also help to make the science program more meaningful for both students and teachers.

## SECTION 4 LEARNING OPPORTUNITIES FOR CHILDREN

### Introduction

The heart of a science program is represented by the learning opportunities offered to children. Teachers are continuously seeking to improve the quality of teaching-learning experiences and to find new ideas for activities which implement the objectives of a science program. The issues of *Science and Children* have been replete with articles which describe classroom activities.

This section is representative of the many accounts of activities found in the first 24 issues of the magazine. The experiences described cover a wide range of science content and of work with children from pre-school age through the upper elementary grades. Other ideas are for teaching-learning experiences which can meet the needs of children of varying abilities and interests.

The first part of this section includes articles which describe some general teaching procedures, applicable to many science topics and to different age groups. The others are specific accounts of learning experiences and present detailed teaching procedures. They are organized according to the broad areas of content: living things, earth science, astronomy, chemistry, physics, and mathematics. Various teaching procedures, such as experimentation, observation, discussion, classification, organization of ideas, and record-keeping are described in these accounts of classroom activities.

It is in no way suggested that a teacher will find it useful or wise to replicate exactly the described activities. Certainly, a teacher will want to select and to adapt the experiences, depending upon a particular teaching situation. Also, it is important that the outcomes of these teaching-learning experiences be evaluated on the basis of pupil growth. These articles are intended to give practical help to a classroom teacher in the implementation of an effective program of science for elementary-school children.

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# *Are You Teaching Science Unscientifically?*

"The sun is 93 million miles away from the earth." —"The moon has no atmosphere."—"At night birds navigate by stars."—"The sky is blue."

When one hears these "facts" doled out in our classrooms, he cannot help but wonder what children think about science. Can they help it if they think of science as nothing more than a neat package of final answers for the many questions that people have about their environment? Is this what we want our children to see in science? Do we want them to perceive science as a finished product or as a continuing process? Do we want them to believe that the answers which science provides are absolute and final, or that they are tentative, changeable, and subject to revision?

Science is often taught dogmatically and unscientifically in many of our schools and colleges. The "this-is-it" attitude seems to permeate much of our science teaching.

When we teach this way, students get a distorted view of science and are seldom, if ever, exposed to science as a process; they miss the opportunity of perceiving science as man's attempt to interpret the universe. They do not see the skills and the attitudes which make up the scientific process. They fail to develop any skills, and consequently many of them miss the chance of becoming interested in science. What makes a scientist is not how much information he has stored in his memory, but the actual training he receives in the rigors of the scientific process: how he wonders about phenomena, how he observes, how he sets up controlled experiments, his willingness to withhold judgment, to admit that he is wrong when there is ample proof, and how much he realizes the limitations of science. These are some of the important traits that make up a scientist. Children are not given a chance to develop these traits when they only experience science as a group of final absolute "facts." This type of teaching defies the very goals of teaching science. How can we possibly foster "intelligent doubt" through dogmatism? How can we promote questioning and inquiry in our students through absoluteness?

Many of the so-called facts which we teach today will probably become obsolete a few years from now. What will this do to our pupils? In all probability, many will remain scientifically illiterate because they do not understand that what we know and teach today is just a step in man's never-ending quest for knowledge about his environment.

Now! To what extent do *you* teach science unscientifically? What if you do? What can you do about it?

You need to approach teaching science in a different way and help your children distinguish between fact, hypothesis, and theory. You do not do this by giving them a lecture on the differences among the three. You can do it by allowing the children to experience the process of science in the class room or laboratory. For example, if you are studying plants and seeds, you might ask the question, "What do seeds need in order to germinate?" You can ask the children to respond to the question by making *guesses* about the *possible* factors which they *think* are necessary for seeds to germinate. When these are listed, you can ask them if these are established facts, or guesses (hypotheses). The next step would be to find out which of these guesses is correct and which is not. To do this, the students can design their own experiments, observe what happens to the seed under the conditions established, and report their findings to the class. Then the group can draw the conclusions which the observations warrant. This method of teaching will help them experience many of the components of the scientific process. Also, you will have provided them with an opportunity to develop some of the skills and attitudes of a scientist.

### Easier To Tell

It might appear easier to tell the students what will happen to the seeds and which guesses were correct. Telling takes less time and more subject areas can be covered during the year this way. However, it is well to remember that "talking is not teaching," and "listening is not learning." Only if you allow the students to guess, experiment, observe, and draw conclusions so that *they* can perceive science as it really is, then and only then will you be teaching science scientifically.

# Head Start To

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ON A completely paved playground, there was a small crack where some ants were struggling to live. One preschooler saw the ants and cried, "Baby cockroaches! Let's kill them." An anthill, which offers the middle-class child an endless source of delight and information on social insects, represents a formidable enemy to the disadvantaged child. All insects are dangerous intruders and must be destroyed.

A similar episode occurred in a HEAD START program when a teacher showed her students a hamster. At first, the children expressed fear, and they asked the teacher to destroy the hamster. To them it was a rat that would bite and hurt. Even in a cage, it represented danger. The teacher had to provide many positive experiences before the children could accept the hamster as a pet and interact with this animal in a positive way—feeding it, making it comfortable, playing with it, and enjoying it.

Early firsthand science experiences for young children are regarded as essential if science literacy is to be achieved. During the summer of 1965, with over half a million disadvantaged children receiving their first taste of school in HEAD START programs administered by the Office of Economic Opportunity, a number of teachers reported that the lack of venturesomeness coupled with fear and misconception were the greatest impediments to science experience. Curiosity, a child's greatest motivation to exploration and "discovery," had to be encouraged in many children who had become overcautious and anxious as a result of the environmental hazards in their lives.

Only through interaction with classroom animals do children eventually recognize that life must be respected for what it is. Gradually, the child who fears the rodent and wishes the ant destroyed must be helped to see the place of living things in the scheme of life, to understand and enjoy certain animals both domestic and wild, to appreciate the interrelationship of plants and animals (even in an aquarium), and to delight in songs of birds and the esthetics of nature.

Teachers of young children always strive to bring these firsthand experiences into the nursery and kindergarten. The HEAD START teachers, however, must have a greater awareness of children's past experiences that can impede science instruction in order to build positive attitudes from direct science experiences.

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NOTE: Additional information about the Head Start Child Development Program can be obtained by writing to Project Head Start, Community Action Program, U. S. Office of Economic Opportunity, Washington, D. C.

# Discovery

In teaching health, which usually includes hygiene and nutrition, the teacher again must recognize that some families lack even the bare minimal facilities and bathroom equipment. One HEAD START teacher taught her lessons with resourcefulness and empathy, encouraging the children to improvise at every turn:

> *"Did you use your toothbrush? The corner of a washcloth is a very good idea. You had no toothpaste? You used salt? That was fine indeed. Salt does clean your teeth. It rinses off nicely, too, doesn't it? . . . Did you hear that John had a nice, warm bath last night! The faucets are fixed, and so is the drain. Wasn't that fine! . . . Judy has a*

*new towel. It's her very own, and she hangs it on a special hook."*

During the entire discussion on personal cleanliness, the teacher could never take for granted that such essentials as toothbrushes, towels, plumbing, and warm water were available. She continually had to be aware of the living conditions of the children. They needed endless encouragement to adjust to makeshift and substitute arrangements that were in keeping with their present situation.

A limited, monotonous diet is the disadvantaged child's prevailing experience with food. Adequate quantities and varieties are hard to come by. They are generally absent from the typical eating patterns of the poor. Instead, there is a concentration of carbohydrates and fats with a conspicuous lack of vitamins, minerals, and proteins.

The pleasure of gracious eating and the opportunity to make food choices are rare. Thus, breakfasts, lunches, and snacks provided by HEAD START helped to compensate for these poor nutritional habits. Teachers pointed out again and again that as the summer developed, the children talked increasingly and joyfully about food. They also observed that school-given nutrition increased alertness and good spirits. Even enjoyment, social graces, and lively table talk emerged as a result of the pleasant eating arrangements.

### Simple, But Meaningful

Direct experience for HEAD START children works the same magnetic lure to learning as it does with all young children whose most available and dependable learning tools are sensory-motor based. Only after these vivid, firsthand experiences have been rich and plentiful can the child learn vicariously about science.

Ordinary experiences can be given meaning if approached with a child's capacities and environment in mind. Such a simple activity as opening an apple, dividing it into wedges, and identifying and observing relationships exposes the child to the meaning of discovery. He can note how the core structure differs from the rest of the apple, how the seeds fit in their place, and how the skin surrounds the fruit. The wonders of life—even in a simple piece of fruit—the star-shaped seed case, the pericarp, the perfect way in which the seeds are contained therein—open up for the child a heretofore unrevealed, exciting world of science.

Once the initial experience has been made, other fruits are compared for color, texture, and taste. Then the children test theories. At first the child sees similarities, then he finds differences: pits of citrus fruits, peaches, plums and cherries; or the very tiny seeds of the strawberry—all different, yet, in some ways alike.

The world of asphalt, brick, concrete, and falling plaster is the world in which the urban disadvantaged child lives day in, day out. Lessons in science must help him to build an appreciation of the effect of rain, sunlight, dampness, and humidity upon the conditions of growth and behavior. A short walk to a nearby park opens countless vistas. Bob notices that the birdbath is empty and the birds are looking for water. Debbie sympathetically agrees, "I'm thirsting away, too."

Children stop leisurely to touch the grass, shrubs, and flowering plants. They talk excitedly about the shape and color of a leaf, the formation of a cloud, the feel of burrs upon their clothing, the oozing of milkweed, the activity of butterflies, and the surprises found under rocks. The teeming world of insects on a vacant lot brings forth many observations, discoveries, and inquiries.

In the physical sciences, children's interests are as great as in the life sciences. A flashlight is an endless puzzlement and a motivating force to children. Naturally, it must be taken apart to see how and why it works. When the dry cells are removed, the problem of assemblage must be solved—first through trial and error, then through the principle of circuitry. Under what conditions will the lamp light? The children become increasingly more cognizant of the various conditions in which the lamp will and will not light. In one instance, the intensity and persistence of manipulating wore

## Head Start To Discovery In Science

the device out so that replacement was a constant need—this is an important consideration in such programs.

In another HEAD START group, a clock afforded no end of adventure. The boys would take the wheels apart one by one, get at the mainspring, test its springiness, and attempt to reassemble the clock. Even though the reconstruction was unsuccessful, the experience helped move them in the direction of many fascinating discoveries in mechanics. As the children were observed, it was apparent that frustration is a natural part of learning when it is coupled with opportunity for discovery.

### A Sense of Achievement

By its very nature, science affords the child a great opportunity for self-instruction, autonomy, and a sense of achievement. This is one field of learning where the adult is well rewarded by nonintervention processes. A child's "eureka" is the teacher's greatest reward. One common distortion about a child's discovery processes is the presumption that commercial materials are the only materials providing this opportunity.

From our observations, household and familiar environmental materials can be rich sources of sensory-motor exploratory activity as well as cognition. A nest of mixing bowls that can be taken apart and put together may be one of the most familiar types of educational equipment to the toddler. A preschooler can easily become absorbed in numerous bric-a-brac, cooking utensils, and just about anything that has weight and occupies space.

A home environment that is sterile, hazardous, and meager inhibits natural curiosity, jades interest, and dulls initiative and self-direction essential to the enterprising activities that are linked with the development and nurture of curiosity. Both home and school should be designed to open doors for the young child through a rich variety of simple materials and resources. A magnet, a bird feather, a pebble, a shell, a living snail—each stimulates a flood of inquiries, associations, and descriptions that lead, in turn, to communication, language skills, and continued investigation.

### Understanding and Guidance

Science experiences offered to disadvantaged preschool and kindergarten children are no different fundamentally than those offered to any other group of similar age. There must first be a rich, permissive environment. A nondirective teacher with faith in the child's ability to use his natural, individual, idiosyncratic methods is required. The teacher must also be available to take on the resource role when the child has pushed his efforts to the limit. In critical moments of learning, he needs an outstretched hand. Without this guidance, the child's total effort may be wasted. Giving up is one of the great tragedies of the learning process. It occurs—not when the adult denies the answer—but when he supplies the answer or disrespects the learner. It therefore behooves the teacher to cherish and keep learning open-ended.

To start the young child on the road to literacy in science, it is important to nurture the natural wonder, curiosity, and excitement the child has for his physical world. The process approach in science is as vital during the preschool years as it is throughout life.

The perceptive teacher blends the experience of wonder with the underlying appreciation of relationships. In all groups, too, children differ in their abilities, sensitivities, and perceptions. The keen teacher is quick to permit a child who comes with "more" to enrich a child who comes with "less." HEAD START teachers were impressed with the number of children who already showed evidence of abilities in manipulative skills, language expression, science concepts, and feelings of great sensitivity and empathy toward people (even though suspicious of most animals). Wherever adventure in science was valued, the programs were alive and exciting. When the teacher failed to provide firsthand science experiences, the dropout was apparent even in these small groups. HEAD START, like any other preschool program, is directed and designed for continuous adventure and growth in science education. The eventual success of the project lies in how well children are helped to understand their natural and technical environment.

# Developing Concepts About Science In Young Children

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How do we encourage young children to develop concepts about science? Gans, Stendler, and Almy say that too many classrooms "neglect the importance of firsthand experiences in developing concepts in children."[1] They add that while five year olds experimenting with a thermometer "would not be able to verbalize their procedure, they were actually using the scientific method." Heffernan and Todd also stress the importance of the scientific methods in developing concepts.[2]

John Dewey believed children were capable of experiences with the scientific method and reflective thinking even though they were not aware they were using it. Dewey's approach may be paraphrased as follows: (a) the child should be engaged actively in a meaningful experience; (b) from such experience, a genuine problem should arise; (c) he should be guided in the collection of data relevant to solving the problem; (d) he should set up a tentative hypothesis or possible solution to the difficulty; (e) the tentative hypothesis is then tested.[3] As a result, it is assumed that the child will be able to continue his experiencing with greater understanding.

The uncomprehending adult frequently asks, "How can a mature theory of developing meaningful concepts be practically exemplified and encouraged from the children's activities, which often seem pointless, uncontrolled, and meaningless?" Let us look more closely in order to find out: (a) how to develop concepts from the natural activities of children; (b) how to determine what the role of the teacher is to be.

Perhaps one example, typical of nursery school, will suffice for the former. The three year olds were playing with newly fallen snow and making the most of this experience, when it became time to go indoors. A number of them responded to the teacher's call carrying balls, or handfulls of snow. "Please let me take it in. I want to play with it inside." The teacher listened to the requests. "Silly," said another child, "it will be water." "No, I want to play with it. Why can't I?" insisted one little boy. At this point the teacher, noting that there was a difference of opinion and that this seemed to arise from a simple genuine problem, produced a pail and said, "Timmy wants to play with the snow indoors. Paul says it will be water. Marie wants to use it for doll food." Thus, she summarized the very simple data supplied by the children. "What shall we do?" asked the teacher. "Put some in a pail, take it to our room, and pretty soon we will see water," said Paul. Although very simple, this was a tentative hypothesis useful to try out one possibility. The teacher smiled and said, "All right, let us find out what will happen. We shall see whether Timmy and Marie can use it, or whether Paul is right." Needless to say, the testing proved quickly and conclusively that snow taken indoors would melt. The word melt was used to designate the concept resulting from the simple experience. Further related activities, such as putting snow in the kitchen refrigerator, on the hot stove, and outside on the window sill were carried out to see whether melting would result. The concept of melting was used freely during snack and lunch time discussion in relation to such other items as ice cream and frozen foods. Thus, we have a simple illustration of the development of a concept about science.

Other experiences from the preschool and early grades, useful in developing concepts, range from how to repair a flashlight that suddenly stops working in the building block garage made by four year olds, to how to adjust a door bell to ring in a first-grade play house, to how the crickets, kept in the kindergarten, chirp, or to finding if a coleus slip will make a new plant for the second grade. The care of a mother rabbit and her babies can be a source of scientific thinking which results in countless concepts about science. The same rabbit and offspring will, of course, be the source of concepts of greater complexity to seven year olds than to four year olds.

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[1] Roma Gans, Celia Stendler, and Millie Almy. *Teaching Young Children*. World Book Company, Yonkers-on-Hudson, N. Y. 1952. p. 241.

[2] Helen Heffernan and Vivian Todd. *The Kindergarten Teacher*. D. C. Heath and Company, Boston, Mass. 1960. p. 175.

[3] John Dewey. *Democracy and Education*. The Macmillan Company, New York City. 1916. p. 192.

The very simplicity of the three year old's snow experience should clarify the role of the teacher. This does not deviate in basic theory whether the teacher is guiding children to understand the basic properties of snow or is encouraging them to find out how a cricket makes his chirping sound. Concepts in science can be developed from the natural activities of children when they are encouraged to pursue their problems through to satisfying conclusions. Their understanding of these conclusions function as concepts which may be verbalized and used for further experiences. This teaching method is quite different from telling children about experience and then asking them to exemplify the concept already given. Although the latter is concise, easy, and faster, it is not nearly as meaningful, developmental, and conducive to real understandings.

The teacher's role may be played in one of three possible kinds of situations: the *incidental,* when a grasshopper is seen on the doorstep; the *unexpected,* when a parent arrives at noon with a baby kitten; and the *planned,* when the teacher and group decide that having chosen to have a pet white mouse rather than a small green turtle, they have to solve problems revolving around suitable living quarters, proper food, and rules about handling. In the first two instances, the teacher's role determines whether much or anything at all is to be developed from the incidental and unexpected situations. The last is usually less of a test of the teacher's initiative. In the incidental and unexpected situations, the teacher needs to consider possible ways to develop worthwhile concepts even though, at the start, she may know little about a Dutch rabbit, a box turtle, or milky quartz.

The teacher's role in developing concepts about science may be summarized by the following traits:

1. Willingness to explore and find out with the group because the importance of science, its method, and its implications in the lives of children are realized;
2. Knowledge of where to acquire further necessary information about simple problems which may arise in science;
3. Knowledge, to which more is constantly added, about plants, animals, and inanimate objects of scientific interest developed through previous experiences and available as functional data for problems which may arise;
4. Conviction that children's experiences, fumblings, and efforts to solve problems within their general capabilities are time-consuming, but far more valuable than the learning of a quick rote answer;
5. Conviction of the importance of trying out (where safe), of failing, of reassessment, and of retrial;
6. Awareness of the breadth of opportunities to utilize new concepts and of the possibilities for constantly extending them;
7. Awareness of how to relate scientific concepts through continuous, meaningful experiences. For example, the concept of how a male cricket chirps and of how a female cricket lays eggs with her ovipositor may be developed into the concept that a male and female cricket perform separate functions.

Above all, the role of the teacher requires the realization that settled, adult acquired knowledge comes as the result of reformulating experienced situations in which there has been enough interest to work through a problem to a satisfying conclusion. The conceptual result is a mere resting place before further experiences and the problems which arise from within them utilize this concept as data in the next development of learning.

To develop science concepts scientifically, it is important to learn how to do it while the child is living through his early childhood years. We must be aware of the many opportunities lying about us which may be developed into concepts about science through which young children may gain greater mastery of themselves and their environment.

# SCIENCE for the EDUCABLE RETARDATE

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Can we, as educators, justify the inclusion of science in the curriculum of the retarded? Or perhaps the question should be; Can we afford not to include this area of learning? The impact of science and technology on all our lives needs little discussion. Retarded pupils eventually grow up and a great majority of them may become contributing members of our society. It is our responsibility as educators to be as vigilant about what goes into the curriculum of the retardate as we are about what stays out. Yet, nowhere in the literature on the subject does any leading authority in the area of retardation make mention of science as a necessary part of the learning and living experience of this group of children.

Our goal for the mentally retarded remains primarily what Hungerford (4) identified as the "key problem," the achieving of vocational and social competence. However, we are living in a different world today than the one in which a child was born into only last year. It is not possible for the educable retardates to function efficiently and to become contributing members of the community without some understanding and insight about our ever-changing world.

The number of mechanical and electrical devices manufactured in increasing numbers and at diminishing costs are available to all segments of our population. The mentally retarded will have continuous, personal experience with more and more of these new devices as time goes on. The toaster, electric can opener, washing machine, and television are now part of the normal American domestic scene. In order to cope with these appliances, to use them more effectively, and be aware of some of the hazards and safety factors, these children need some understanding of the simple, underlying scientific principles involved.

Our technology is creating many new kinds of job opportunities. *The Dictionary of Occupational Titles* has been unable to keep pace with the many new industries and positions. Undoubtedly, there will be many simple jobs created that will come within the range of abilities of the educable retardate. The jobs will require a minimal understanding of basic scientific skills. These understandings are, for the most part possible, for the retardate to acquire as will be shown to some extent later in this article. It appears that in order to fulfill our goal of social and perhaps vocational competencies, we should explore the possibilities of utilizing science as part of the curriculum for the educable retardate.

### Objections to "Glamorous Subjects"

The negative reaction to the inclusion of so-called "glamorous subjects" for the retarded has traditionally taken two lines. The first objection is that the subject matter of a scientific course of study appears not to have a specific vocational application. As time goes on, preparation for the specific skills of a given job are being taught in industry, and large corporations are establishing facilities in which to train workers. According to Clark and Sloan (2), business and industry want the public school to provide training in the basic skills of language, number, and in general methods of work, so that those who seek jobs will be well grounded in these areas. With this in mind, perhaps educators should attempt to develop a generalized ability on the part of the retarded pupils to adjust to different circumstances. At the present time, the curriculum for the retardate stresses programs of specific training in vocations. Educators have neglected the possibility that the retardate may be able to generalize and/or improve his capacity to adjust to different or new situations.

The second argument states that since science learning requires considerable abstraction, it would not be comprehended to any degree by retarded children. The most widely held view on the conceptual and learning characteristics of the retarded is that their abstraction capacity is, at best, quite limited. Baker (1) says, ". . . they tend to have concrete abilities rather than abstract: they have limited powers of reasoning, visualization, and similar mental traits." Ingram (5) states, "It is more difficult for the mentally handicapped children to 'pick up' basic principles and concepts because of their poor insight and low ability to generalize." Garrison (3) reports, "The differences in the learning ability of those classed as mentally retarded and the average child is most pronounced in those activities that involve reasoning and problem solving in which symbols are used." Scheidemann (8), with finality, decrees, "Judgment, the capstone of reasoning, is not encountered in any type of feebleminded." These statements, made on the basis of subjective observations, opinions, and IQ data, have served as a foundation for those who have undertaken to construct curricula for mentally retarded children.

This type of thinking has been responsible for many glib clichés referring to the characteristics of mentally retarded children. Until educators gain more knowledge about the learning characteristics of mentally retarded children, they will remain in the same position that Itard, Decroly, Montessori, and the other pioneers in the field found themselves. Their programs were based upon a philosophy that had little foundation in empirical information. Many programs today have not exploited the additional sophistication provided by researchers since the days of these early workers. Programs have been geared to imparting habituated responses to specific situations.

Johnson (6) reports that learning studies undertaken in the last decade, comparing the learning characteristics of retardates and normal children, show that the retarded child learns in much the same way, following the same laws of learning, as the normal child. These recent studies seem to indicate the feasibility of attempting new methods and new curricula subjects for the retardate.

In line with a policy of constantly re-evaluating their educational program, Katherine D. Lynch, Director of the Bureau for Children with Retarded Mental Development of the New York City Board of Education, gave her permission for a study [Katz (7)] to be undertaken which had, as one of its major goals, the feasibility of teaching science to educable retardates. This study was conducted with six classes of retarded children in three academic high schools. The goal of the study was to test the ability of these pupils to learn the scientific material presented and to measure their interest and ability to transfer the knowledge they acquired to situations other than those presented in the course of study.

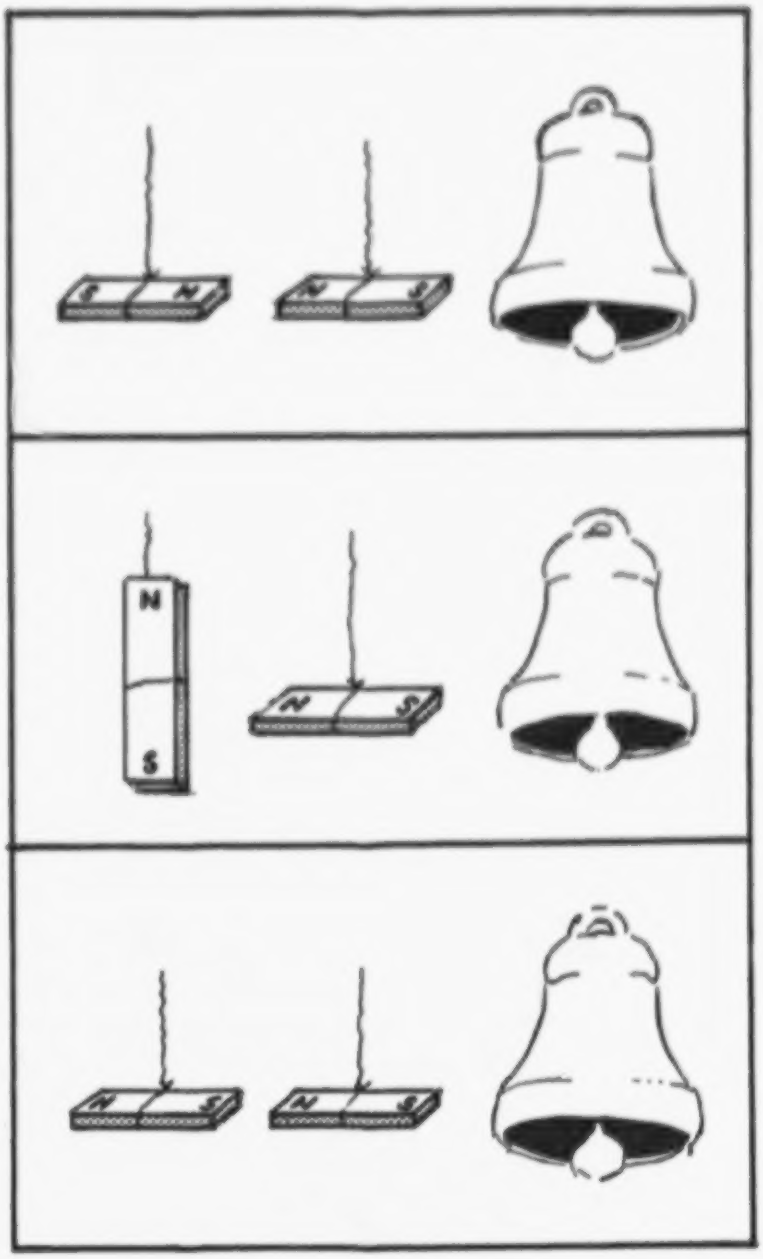
### Lessons in Magnetism and Electricity Used in Study

The area of the science curriculum chosen was the field of magnetism and electricity which included material fundamental to the understanding of the bell, motor, telegraph, and other electromagnetic devices. The subject of magnetism and electricity is accepted in science education as an introduction to science in lower grades. The ideas presented were mastered quickly by children and the experiments performed proved sufficiently dramatic to capture and sustain their interest.

The results of this brief study showed conclusively that these children could learn the scientific material presented with facility. They demonstrated, by special tests designed for the study, that they had also acquired the ability to transfer 20 principles that they had learned to unique situations in order to solve problems. All the scientific material was received well by both boys and girls in all six classes taught during the study.

An example of one of the problems solved may be seen in the illustration. The children were taught that like poles of magnets repel and unlike poles attract. They were tested on their ability to relate this information. The children were then confronted with problems, such as the one in the illustration, where they were asked to put a cross on the picture in which the magnets would ring the bell. This required that they apply the principle they learned to solve a problem in a unique situation which they had never encountered. A significant number of children demonstrated their ability to solve this problem.

If it is accepted that the retardate can learn some of the principles related to magnetism and electricity, then it may be assumed that some of the other areas in science might be profitably explored. Under the heading of science are aspects of learning: such as, the study of living things (plants and animals), or good health through proper food, rest, exercise, and disease prevention. Units have to be developed that are pertinent to the development of this group of students and are



based on some of their experiences. Studying the safety devices in the community; such as, fire alarms and traffic lights; and the everyday precautions necessary in the handling of tools and machinery can be important contributions of science to the curriculum. The weather, and its interpretation for proper dress is functionally important to this group of pupils.

In light of the limited evidence, the prescription is not so advanced that all programs immediately include science in the curriculum for the educable retardate. However, in keeping with the tradition of constant self-criticism and evaluation, this area should be explored scrupulously for the possibilities it offers. Science, as subject matter, is a vast resource that has never been formally tapped by the curriculum architects or leaders in the field of special education. It is a timely subject that has high inherent motivational value. The many concrete demonstrations that are possible in this area can help bridge the gap from concrete to abstract thought. The possibilities that the understanding of simple and basic science learnings can eventually bring social and vocational adjustment to the retarded child should be weighed with care.

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# "Watch Your Language!"

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EVERY YEAR more and more elementary school teachers are teaching science, and in greater depth. As these teachers gain confidence, they attempt to teach more than facts. They try to encourage pupils to think, to form correct concepts, and to reason their way to formulation of some of the theories and laws of the sciences. Such enterprising teachers should be cautioned against teaching some widely prevalent misconceptions and errors.

The self-contained classroom makes it necessary for the elementary school teacher to be something of an expert in all fields of knowledge. While this is really too much to expect of any teacher, we can hope that those to whom we entrust the education of our children can acquire enough background to avoid serious errors. Unfortunately, in spite of the tremendous growth of interest in the sciences on the part of young children and the ever-increasing need for an informed public, the background of most elementary teachers — even recent graduates — is seriously deficient in the sciences. This is particularly true of the basic principles, concepts, theories, and laws in the area of physics, the most basic of the sciences. Thus, most teachers must educate themselves on the job and are making heroic efforts to gain knowledge in science.

The most common sources of information are the elementary school textbooks with their accompanying teacher's editions or manuals. Unfortunately, many of these create confusion because they contain either misconceptions in physics or ambiguous language.

### What Is WORK?

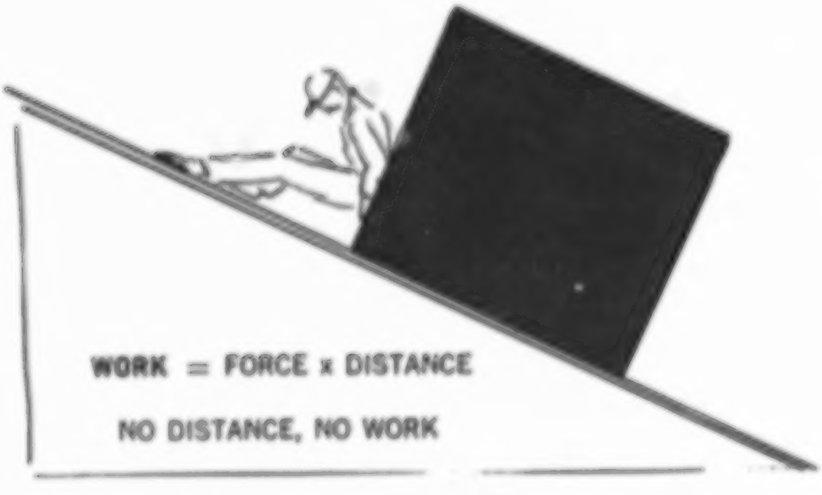
For example, the use of the word "work" is often confusing. (Work, in the physical sense, is done only when a force results in motion.) All but three of ten elementary science textbook series examined by the author use the expression: "Work is made easier by the use of an inclined plane (or another of the simple machines)." This statement can be interpreted in several ways because of its ambiguity. It strongly suggests that more work can be obtained from a simple machine than is put into it. This is, of course, contrary to the law of conservation of energy: *Energy can neither be created nor destroyed; it can be transformed from one form to another with exact equivalence.* The error is compounded in many textbooks by addition of the statement: "The wheel and axle make man's work easier. The energy that he uses can do much more work." Actually, *less* work can be obtained from a simple machine than is put into it since some of the input work is converted to heat because of friction.

The general statement "machines make work easier" is objectionable because its ambiguity makes the stated interpretation not only possible, but probable. Machines do lighten our burden if by machines we mean engines and motors. But, engines and motors do not make our work easier; they do our work for us by transforming electrical energy, heat energy, or some other kind of energy into mechanical energy. In any case, this argument does not apply to simple machines, since with simple machines there is a direct relationship between work input and work output.

### FORCE

Another common error found in many elementary textbooks, which is basically related to the preceding, is the confusion in the use of the terms of force, work, and power. Some of the texts examined by the author state: "Running water makes a force called power." This is a serious error. Force and power are not the same thing at all—any more than distance and speed—although in both cases the two are related.

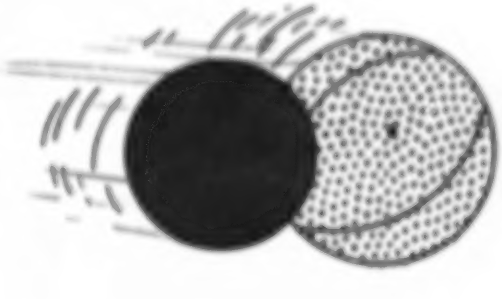
Force may be simply described at the elementary level as a push or pull. This applies to magnetic, electrical, and gravitational forces, as well as forces transmitted by contact between objects. The work done on any object ("body" is the term commonly used in physics) is the force exerted on the object (body) multiplied by the distance the object moves in the direction in which the force acts. Thus, work and energy are essentially the same thing; but they are not the same as force, since work or energy involves distance as well as force. Energy may be transformed from one form to another or back into work. Most of us would not confuse distance and speed, because we are familiar with these concepts. Yet distance is involved in speed, and force is involved in work.



### POWER

Power is not the same as energy or force. Power is the rate at which work is done or energy expended. It is work or energy per unit time. One nuclear explosion may scatter a large hill over the countryside in a few seconds. It might take 100 men many years to accomplish the same thing. The 100 men do the same amount of work as the nuclear device, but their power is much less.

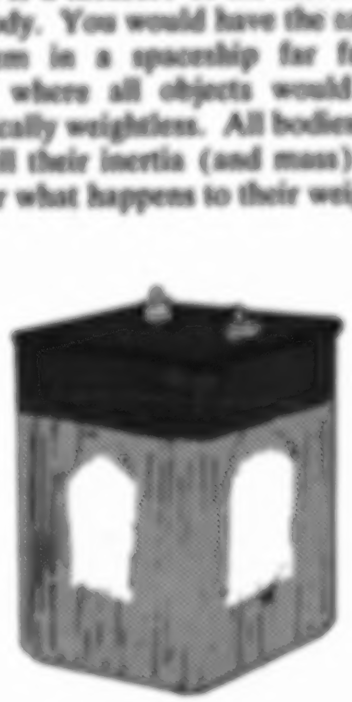
Another example may help to clarify these terms. It may take a man weighing 300 pounds ten seconds to climb a flight of stairs. A man weighing 150 pounds may be able to do the same in five seconds. They both have the same power, but the 300-pound man must exert twice as much force to lift his weight.



### MASS and WEIGHT

Another pair of terms which are frequently confused in elementary textbooks is mass and weight. They are quite different, and the difference increases in importance as man begins to reach out into space. *Weight is a force.* The weight of a body is defined as the "pull of gravity"—the earth's gravitational attraction—on the body. We now have to broaden the definition to include the gravitational pull of the moon, Mars, or other planetary objects, but weight is still a force.

Mass, on the other hand, is the *quantity of matter in a body*. This does not change as we take the body away from the earth. We can speak of "weightlessness" but not "masslessness." We can get some idea of the mass of a body by giving it a quick shove to get it moving, or if it is already moving, by trying to stop it. Which would you rather try to stop: a basketball or a bowling ball, both traveling with the same speed on a horizontal surface? In this case, we are talking about mass, which is a measure of the inertia of the body. You would have the same problem in a spaceship far from earth where all objects would be practically weightless. All bodies retain all their inertia (and mass) no matter what happens to their weight.



### ELECTRICITY

Another common misconception found in many textbooks is typified by this statement: "The drycell makes electricity." Electrical sources do not *make* electricity. They convert other forms of energy, usually chemical or mechanical, to electrical energy.

The use of the ambiguous term "electricity" may be justified as a simplification, particularly in the early grades of the elementary school. The term is sometimes used when referring to electric current—at other times when referring variously to charge, potential difference (voltage), electrical energy, or power. We should use extreme care, however, in the use of the general term "electricity" when referring to electrical charge or current especially.

You have, perhaps, heard the statement that when a light is turned on "electricity flows into the light," suggesting that when the light gets "full of electricity" it glows, or that it glows because it is "using up" the electrical current that "flows into" it. Both concepts are completely erroneous. On the basis of the second concept, it is commonly, but mistakenly, believed that if two identical bulbs are placed in series in a circuit, one should be dimmer than the other. The misconception is: "The first one uses up some of the current, and therefore less current flows into the second one." Experiment shows, however, that both appear to be equally bright.

Every elementary school teacher should acquire a clear concept of electric current. In a conducting solid, current consists of moving electrons, each one of which bears a small quantity of electric charge. The greater the number of electrons (and therefore the greater the quantity of electric charge) per second *flowing through* an appliance, such as a light bulb, the larger the electric current. None of the charge is "used up" in an appliance. Thus, just as many electrons as enter one terminal of the appliance must leave the other terminal each second.

There can be no "piling up" of charged electrons anywhere in any electrical circuit which is likely to be considered in elementary school science—nor any "leakage." Thus when two or more bulbs are connected in series, the current through each must be the same. This is similar to the flow of water through a series of pipes and closed tanks where there is only one possible route for the water to follow. If there are no holes and all pipes and tanks are full of water to begin with, the current must be the same through each, *i.e.*, the number of gallons per second flowing through one tank or connecting pipe must be the same as through any other. This is true because the water cannot pile up or leak out anywhere.

What then, is "used up" in a light bulb as it glows? Electrical energy (energy of moving charged electrons) is changed to heat and light energy. In this sense electrical *energy* is "used up."

### How To Avoid Mistakes

Many examples of misuse of language are present in other various sources that teachers use in the classroom. How does a teacher meet the challenge of presenting correct terms and concepts to his students? One way is for a teacher to acquire at least enough background so he can judge an author's presentation. Another way is to have a science textbook committee review for scientific accuracy all textbooks that are to be purchased, or have been purchased, by the school system. This committee should include college teachers, laymen who have a technical or scientific background, secondary school teachers, and elementary school teachers.

When mistakes are found in a text that teachers are using (or thinking of buying), a notice should be sent to all teachers pointing out the errors and correcting them. At times, the committee might recommend that a part of the book be omitted because of scientific error. Letters should be written to the publisher of the book bringing the errors to his attention so that they can be corrected in later editions. Workshops could be conducted to help teachers gain an understanding of a concept which involves the correct use of language.

These approaches and others will help the teacher to use the language of science correctly. They will also help the students in our classrooms to learn the correct meaning of scientific terms.

# Problems of PROBLEM-SOLVING

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The available literature on teaching science from the problem-solving approach is prolific with reasons why it should be done. Descriptions of exactly "how" to go about teaching from this approach are meager.

Learning to solve problems in science, like learning to knit or to play golf, is done by trying to do it. (Learning by doing!) Perhaps this is why most descriptions of how-to-do-it really do not tell us how; therefore, we are not prompted to begin teaching science in this way.

How does the problem-solving method differ from the usual method of teaching? The chief difference may well be that you will surely "cover" less content than you would if you used a book. Science educators agree that students should "uncover" knowledge for themselves. The teacher's role is to provide an atmosphere conducive to thinking and to give guidance to that thinking. Teachers and children using this method will not be seeking verification of an answer which has been decided upon ahead of time. This may cause some difficulty if one is working with children who have not had previous problem-solving experience. There is evidence to suggest that children often change reports of observations if they do not agree with predetermined answers. Preconceived answers tend to curb any thinking on the part of the student.

## What Is Your Task?

The hardest task to face is to resist giving away possible answers to the problem before students have used all the other resources at their command. To maintain your composure through the long silences which occur when children are desperately trying to think, is difficult. Practice is required to develop the habit of countering a student's question with another question. Another requirement of the problem-solving method is courage to embark upon an investigation of a problem to which neither you nor the students know the answer. If children are to become aware of the methods used by scientists, they must use these methods as the scientist does.

## What Is a Problem?

Think of it as a question to which your students do not know the answer. A problem is not a topic heading in a textbook that happens to be stated as a question. These questions can be solved by reading the answer in a textbook. When the answer is known, the lesson is finished. Experience has shown that memorizing answers which have been read or heard by listening to a teacher's lecture are not long remembered, nor do the skills of problem-solving become integrated into the students personal work habits.

Another way to solve a problem is to allow students to become personally involved in trying to find possible answers by reading, experimenting, consulting with others, and by using their intuitive powers. The responsibility for learning is on the student, which is the proper place for it since teachers cannot do the learning anyway. This is the problem-solving, or the "discovery" method which we talk about, but seldom implement in practice.

## How To Begin?

An elementary teacher is often enthusiastic and begins a new technique with the expectation of doing everything in a bigger and better fashion than before. Grand plans are made for complete units and whole semesters of work. After the initial novelty wears off and the enormity of the undertaking becomes apparent, the whole project becomes a staggering burden and the teacher abandons it. The memories of the attempt are unpleasant. This does not encourage the teacher to try another innovation.

Teachers who have been most successful with "problem-solving" have started in a small way. They usually decided to try one problem with the entire class. As teachers become more skilled in this method, other problems can be added to the science program.

Some time should be spent orienting the children before this approach is undertaken. Many of them will have little or no confidence that an idea they "think up" will have any value. If the students learn to exercise their own intuition, instead of depending on someone or something outside themselves, a great deal will be accomplished.

In the beginning, all the children may want to work on the same problem. When an investigative atmosphere has been developed, the student's interests will be diversified. There is no reason why a child or group of children cannot work on a topic of specific interest. Plans will have to be made for specific topics, so that they relate to the themes or courses of study set up for the grade. Permitting children to work in groups has the advantage of making it possible for teachers to allow for individual differences and to make better utilization of the time, equipment, and reference materials which they may have in the classroom.

Science problems, (which *are* problems, and not demonstrations or verifications of something already learned) usually require continued observation, measurement, and data collection. Important science skills and processes can be taught by using a few minutes each day, rather than planning for large blocks of time arbitrarily placed in the weekly schedule.

Since reading pages and pages about problem-solving is not likely to get anyone started, listed below are some problem-solving situations. Perhaps one of these activities will appeal to you or your students.

### Activity I. A Mold.

Many children have had the experience of growing mold on bread. They may know that mold is a plant, and that it is spread by spores which are produced in spore cases. These spore cases can be observed by using a magnifying glass. After this background has been established ask:

1. What else will mold grow on? (cheese, jelly, fruit)
2. Are all molds the same? Is cheese mold the same as that which grows on jelly? Does bread mold grow on fruit?
   a. How can we find out? (Students collect moldy cheese, bread, jelly, or fruit; inoculate other specimens—cheese to jelly, bread to fruit, and so on. Several children can do combinations of their own. Duplicate experiments will add strength to evidence collected.)
   b. How do we know how our experiments are progressing? Help students to devise a chart to be used in recording daily observations, including the approximate diameter of any mold colony that appears. Here is an opportunity to introduce the metric system. This system is used by scientists and can be found in a high school physics book. Children should know about the metric system as well as the English system. Students can also record the dates, colors of mold, when spore cases appear, and evidence that the mold is dying, if this should happen.
3. What growing conditions provide the healthiest colonies of mold? (It is important to remember that the planning of experiments is as important as getting answers. Let students plan to set up mold cultures with varying amounts of water, light, and heat present. If they are unable to figure out how to do this at first, let them mull over the possibilities for several days. If you plan the experiments for them, much of the instructional value is lost.)

### Activity II. Simple Machines.

Traditional lessons can sometimes be converted into problem-solving by simply changing the sequence of the learning. Instead of reading the chapter on pulleys and then demonstrating how they work, try setting up a pulley arrangement on your science table. Let the children try out the pulleys and weights during spare moments over a period of several days. After each trial, the amount of weight lifted, the distance it moved, the force used (using a hand spring scale), and the distance the pull rope moved should be recorded in an orderly fashion. After many trials, have the children consider the evidence. Allow them to make a verbal conclusion about the advantages of using the arrangement of pulleys which was set up. Trials can then be made with different arrangements of pulleys. The children will begin to see for themselves that pulleys can change direction of force, increase the speed and distance, or increase the force, depending on how they are roped together.

In addition to learning about a simple machine, the children have had an opportunity to keep scientific records, measure, and draw conclusions based on their own findings. This unit offers the teacher a chance to practice skillful questioning, without lecturing and memorization.

If you are inexperienced in the use of pulleys, borrow a textbook from a junior high school teacher. Most

secondary science teachers are happy to have the opportunity to give advice, books, and materials to elementary teachers. This gives them the opportunity to learn about the work done by the children in the early grades.

**Activity III. Measurement.**

Provide the children with a 12-inch ruler, yardstick, and a meter stick. Have them measure the length of their room, length of desk, and other objects, using all three measures. The students should become familiar with the units involved and be able to recognize that there will be more yards in a given distance than meters, more centimeters than inches. A meter stick can be made from a slat which is 1½-inches wide and 40-inches long. Have it cut as close to 39⅜ inches as possible. Divide it into 100 centimeters. Note that centimeters can be written as decimals. This activity will allow children to become familiar with two systems of measurement, not to have them memorize equivalent values. When is the English system used? Why is the metric system used by scientists? How are measurement systems developed?

In this activity the teacher has an opportunity to teach the basic concepts that measurement systems are man made; and, therefore, subject to error.

Measurement is a basic skill needed in all science courses. Many of the newer elementary science curriculum projects contain activities that require students to be able to measure.

## Summary

Why do science educators so strongly advocate teaching science by letting children learn for themselves? By now it is apparent that we can no longer teach children a body of knowledge that will serve them well throughout their lifetimes. No one can predict what science content will be valid or valuable ten years from now. Not even scientists can keep up with all the scientific developments in their specialty area. Our only alternative seems to be to familiarize students with the skills and processes which are used by scientists in solving problems as they appear. To do this, we use some of the basic concepts of science as vehicles for learning the skills of investigation.

There is general agreement that science is science, whether it be in kindergarten, high school, graduate school, or a research laboratory. There is no reason why a child cannot pursue a problem that is challenging (but not overwhelming) to him, at his level of understanding.

# Mr. Reader, Mr. Doer, and Mr. Problem Solver

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The fifth-grade children in the classrooms of Mr. Reader, Mr. Doer, and Mr. Problem Solver are studying weather. Each teacher is teaching a lesson on the thermometer.

Mr. Reader has a list of new words on the board: thermometer, degree, expand, contract, and Fahrenheit. He develops motivation for the lesson by explaining that the thermometer is one of the most important instruments for studying the weather. "In order to understand our lesson on the thermometer," he explains, "we must know the meanings of some words." The children discuss the meanings of the words, looking them up in the glossary of the textbook and copying the definitions of the words into their science notebooks. Each word is properly syllabized, accented, and diacritically marked. They have seen that "thermometer" having the word meter in it, is literally "thermo meter" or measurer of heat. Thus the children have developed skill in word analysis.

Now the children are instructed to read from pages 115 to 117 in their textbook to find out how a thermometer works. Having read the lesson, the teacher and pupils discuss what they have read. As a review activity, the children copy a fill-in paragraph from the blackboard which includes the new words in context.

Over in Mr. Doer's room, the children have just read that the liquid in a thermometer "rises" in its tube because it expands with increasing heat. Included in the text is an experiment that illustrates the principle. The children are eager to try it. The teacher emphasizes the importance of learning to follow directions carefully. He writes the following words on the board:

Problem, Equipment, Procedure, Observation, and Conclusion.

"What is our problem?" Mr. Doer asks.

George responds, "How does a thermometer work?"

Mr. Doer records. "What will we need?" The children re-read and Mr. Doer records. "What is our procedure?" The children re-read and give the procedure. A group of children and Mr. Doer perform the experiment. They observe that the water in the tube expands when the flask is heated and the conclusion reached by the class is that a thermometer works on the principle of a liquid expanding in an enclosed, calibrated tube. This was recorded on the blackboard and copied into the science notebooks.

Mr. Problem Solver's class has been studying the effect of heat upon solids and gases. They have seen that solids and gases expand when heated.

**"DOES HEAT MAKE LIQUIDS EXPAND, TOO?" JOAN ASKS.**

Mr. Problem Solver writes the child's question on the board. "What do you think about this question class?" The children respond with their ideas. "How," the teacher asks, "could we find out if heat makes liquids expand? Suppose you discuss the problem among yourselves and see if you can propose a way of finding out." The children have several ideas. Some suggest they put some cool water in a test tube, mark the level of the water, and heat it. This group performs the experiment and thinks the liquid has expanded. Mary's group suggests an improvement—a flask with a tube in a stopper, reasoning that if the water in the flask does expand, the water will "rise" in the tube. This group tries the experiment and finds that the liquid did expand in the tube. "It's like a thermometer," Frank observes. "Is that the way a thermometer works?"

Tom asks, "Does this mean that all liquids expand?"

"How can we check?" Mr. Problem Solver asks.

"We could try other liquids or check in a book," Tom replies.

"I'll look up thermometer," Mary says.

Various references are checked and the generalization "liquids expand when heated" is stated. Alice finds that a thermometer works on the principle of expansion and contraction of liquids.

Mr. Problem Solver reviews, "Joan stated a problem for us. We had several ideas. Sam's group suggested we try heating a test tube of water. Mary's group devised a more sophisticated experiment and observed that liquids expand when heated. Frank saw the application of this principle to the thermometer. Tom showed critical thinking by asking if this necessarily applied to all liquids. By checking in references, we did find that in this case our hypothesis was correct. But," Mr. Problem Solver asks, "what happens to the liquid when the temperature drops?" Once again the class is busy experimenting and drawing their own conclusions.

These are three ways a science lesson might be handled. Misters Reader, Doer, and Problem Solver are representative of the kinds of science teaching taking place in our elementary schools. Mr. Reader uses science to teach reading. Recognizing the natural interest of children in science, he uses science as the motivation for developing word analysis, glossary drill, syllabication, the use of diacritical markings, outlining, and organizing information. The use of science to teach reading is very popular.

Parker has recommended such an approach. On a weather unit, for example, he suggests the first week be spent on introducing the basic vocabulary needed to express the concepts and develop word-analysis skills. The usual chalkboard and class discussion method is a fine approach, here. The next two weeks might be spent with assigned class readings, reports, and demonstrations to illustrate the concepts the children had been developing during a week of reading-and-doing.[1]

Mr. Doer sees science as a doing subject with children actively participating in demonstrations that illustrate scientific phenomena. He uses the activity to develop purposeful re-reading so the experiment will take place as it should and illustrate the principle involved.

Mr. Problem Solver sees science as an adventure in solving problems as well as a body of information. He capitalizes upon children's own questions. He accepts their ideas recording them usually without comment. In this way, he discovers opinions, misconceptions, and shallow understandings. He permits the pupils to explore their own ways of arriving at conclusions, and guides them into critical examination of their own statements. He reviews not only what has been learned, but how the learning has progressed, recognizing those who have made contributions to the development of the understandings.

### Relationship to Goals in Science Education

Judgments concerning the relative merits of these methods bring us to the nagging question of goals. Let us consider the contributions of these three methods in relation to the goals of science education, and in relation to what is known about the learning process.

There is general agreement that *goals* of science teaching should help:

1. Develop an understanding of science concepts and principles for more effective participation in the child's world.
2. Develop an understanding of the processes of science.
3. Develop an understanding and appreciation of the interrelatedness of scientific and technological achievement and our society.
4. Develop attitudes of open-mindedness, deliberation, and critical thinking.
5. Develop skills and abilities appropriate to scientific reading and experiment.

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[1] Don H. Parker, "Reading in Science: Training or Education?" *The Science Teacher,* 30:43-46. February 1963.

The basic principles of *learning* have been stated in these terms:

1. In an effective learning environment, pupils are working at purposes that are real to them.
2. Learning is most effective when the child is motivated by goals which are intrinsic to the learning activity.
3. Learning is effective only when the total situation has meaning for the learner.
4. The learner should be given an opportunity to participate actively in the learning situation.
5. Each child is considered unique in his ability to learn and in his rate of learning.
6. A child learns best when the learning tasks are adjusted to his level of maturity and readiness to learn.
7. Creating a good environment for learning means taking into consideration the total situation in the classroom.
8. Learning is facilitated if it is recognized that for the child, learning has unity and involves the individual physically, mentally, socially, and emotionally.
9. The organization of experiences in a learning situation needs to be viewed from the eyes of the learner.
10. The quality of group process and relationships in a classroom affects the quality of the child's learning of school tasks.
11. Learning is more effective in an environment where the teacher guides and stimulates new interests and helps pupils clarify purposes and develop insights, than in one in which the teacher uses ridicule, fear of failure, and discrimination.[2]

### Contributions by Each Approach

Considering these goals and findings as a background, you can see that each method can make contributions in varying degrees.

For example, the "reading" approach, the "doing" approach, and the "problem-solving" approach all contribute to developing an understanding of science concepts and principles. Each approach can be adjusted to meet individual differences.

Mr. Reader's approach can make a substantial contribution to the development of skills in reading scientific material. Mr. Doer's approach can make a substantial contribution to developing laboratory skills, in following directions, and in using laboratory equipment. However, Mr. Reader's and Mr. Doer's approaches appear shallow in their contribution toward developing understanding of the processes of science, especially in attitudes of open-mindedness, deliberation, or critical thinking.

It is Mr. Problem Solver's approach which is most consistent with the principles of learning and the goals of science education. This approach emphasizes the use of the processes of science to teach science concepts and principles encouraging scientific attitudes and skills. It is most effective in developing the ability to think:

". . . Pupils *think* whenever they encounter an obstacle, difficulty, puzzle, or intellectual challenge which interests them. The process of thinking involves designing and testing plausible solutions for the problem as understood by the thinker." [3]

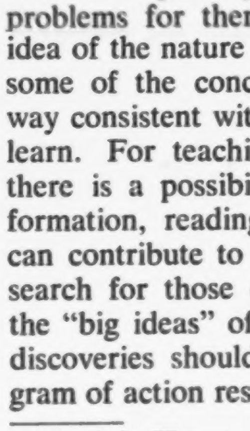
The problem-solving approach is especially effective in providing wide participation among pupils in a social involvement most nearly resembling actual situations in which problems of evaluation, control, tension-management, and decision making are met.[4]

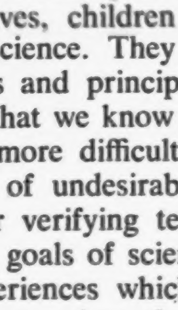
### Problems to Study

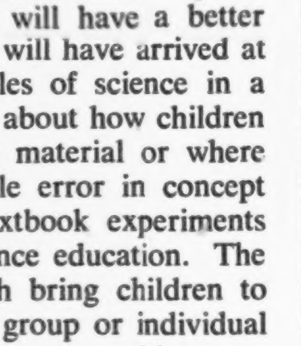
Listed below is a series of "Classics" to which Mr. Problem Solver's approach to the teaching of science in the elementary school can be directed.

1. **What will a magnet do?** What will a magnet pick up? How do magnets react to each other? Through manipulation, even young children can arrive at some principles of magnetism.
2. **How do seeds grow into plants?** Children can devise several ways of examining this process—by planting bean seeds and pulling them up, by planting them in soil against the outside of a glass jar, or by keeping them damp between pieces of glass.
3. **How do various materials settle on the bottom of a quiet lake?** Using gravel, sand, and silt children can discover for themselves how particles typically settle into layers giving us a record of the past.
4. **Can we make a model of the solar system for our classroom?** After sizes and distance are known, this question may lead to a concept of the vastness of space by the discovery through simple arithmetic of the impossibility of constructing a model with the same scale of sizes and distances which would fit into the classroom.

With a quantity of such experiences in working out problems for themselves, children will have a better idea of the nature of science. They will have arrived at some of the concepts and principles of science in a way consistent with what we know about how children learn. For teaching more difficult material or where there is a possibility of undesirable error in concept formation, reading or verifying textbook experiments can contribute to the goals of science education. The search for those experiences which bring children to the "big ideas" of science through group or individual discoveries should contribute to a most exciting program of action research for the elementary teacher.







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[2] Vernon E. Anderson. *Principles and Procedures of Curriculum Improvement.* The Ronald Press, New York City. 1956. p. 106-115.

[3] Goodwin Watson. "What Do We Know About Learning?" *NEA Journal,* 52:21. March 1963.

[4] Donald W. McCarthy. "An Experimental Study of Two Methods of Teaching Selected Chemistry Concepts and Generalizations in the Fifth Grade." Unpublished Seminar Paper, Ohio University, Athens, Ohio. 1962.

# Can You *Prove* It?

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ALTHOUGH the burning candle "experiment" is usually performed to demonstrate that air is required to support combustion, it can provide an adventure in thinking for teachers as well as students. In a recent graduate class in elementary science education, the burning candle experiment provided elementary school teachers with an opportunity to experience curiosity, critical thinking, creative experimentation, and *confusion!*

The problem arose when the class viewed the film, "In-Service,"[1] which presents a traditional burning candle demonstration: A candle, standing in a pan partially filled with water, is lighted. Then a glass jar is inverted over the candle and lowered all the way to rest on the bottom of the pan. The candle stops burning, and the water rises in the jar. The film narrator, Herman Schneider, then comments that, contrary to what *his* science teacher taught him, "the water rising in the jar has nothing to do with the 'using up' of oxygen in the jar." Intentionally not providing an explanation, Dr. Schneider suggests that the audience could learn the answer by doing a little "homework."

When the film was over, the students turned to the instructor for the answer. However, the instructor persisted in volleying their question with: "Why do *you* think the water rises in the jar?"

## The Class Was Intrigued By the Question

Several students said they thought Dr. Schneider was merely using a play on words. They had been taught that the candle goes out because the oxygen—necessary for combustion—is reduced to carbon dioxide instead of being "used up." One student quoted the course textbook to support his point of view:

> The candle will use up oxygen inside the jar until it goes out, and water will rise to replace the oxygen.[2]

Another student disagreed and offered this explanation: "The heat generated by the candle expands the air in the jar; and when the candle goes out, the air cools and contracts forming *a partial vacuum.* The water is pushed into the jar until the pressure on the inside balances the atmospheric pressure on the outside."

When the second student sought the instructor's support in the disagreement, he was encouraged by this reply: "Your explanation sounds logical. Can you think of a way to test, or prove, it?"

After thinking a few minutes, the student proposed an experiment involving two jars, two candles, and an incandescent electric light. The student hypothesized that if the light were turned on next to one of the jars placed over burning candles, the water would not rise as high as in the other jar because the air would not be allowed to cool as much.

The experiment was performed for the class the next day. The students noted that when the candles stopped burning, the water had risen in both jars to the same level. The water levels were marked immediately, and then a 150-watt electric light was attached to the top of one jar. After thirty minutes, the two jars were observed. The water level in the unheated jar had risen almost a quarter of an inch.

Although the class did not think the experiment disproved the "used-up oxygen" hypothesis, they agreed that the experiment did suggest that the contracting air was an important factor in the phenomenon.

Another student suggested that an experiment be set up using a large and small candle.[3] It was hypothesized that the large candle would burn brighter and hotter, but that both candles would go out after the same amount of oxygen was burned. Any difference in the water level would be due to the *difference in the heat factor.*

Although the water did rise slightly higher in the jar over the large-wicked candle, the class speculated that the slight difference was probably caused by the greater diameter of the large candle taking up more water space, thus causing the water to rise higher with equal air displacement.

The next day, two students told the class that they had discovered the "final word." It was, they said, *the cooling and contracting air;* and they had an article from *The Science Teacher* to prove it:

> Air escapes or overflows from the jar because of expansion caused by heating as the jar was lowered over the flame. . . . Air can usually be observed escaping as bubbles even after the mouth of the jar is put into

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[1] This film is produced by D. C. Heath and Company to describe for teachers the nature and purposes of upgrading the teaching of elementary school science.

[2] Elizabeth B. Hone, *et al. A Sourcebook for Elementary Science.* Harcourt, Brace, and World, Inc., New York City. 1962. p. 213.

[3] Large and small refer mainly to the size of the wick.

the water. The rise of water into the jar, therefore, is caused by the higher external atmospheric pressure as the remaining air cools and contracts, producing a "partial vacuum."[4]

Also, they were prepared to prove their point by a demonstration. Leaving the mouth of the jar up, they set afire a piece of paper inside it. They immediately turned the glass over into the pan of water, extinguishing the flame. After the jar had cooled, water had risen into the jar nearly halfway. Because air is approximately 20 percent oxygen, the rise of water in the jar 50 percent of the way could not be due to "using-up" oxygen. The class agreed but then pointed out that because a flame had been introduced into the jar, the "using-up" of oxygen still could not be ruled out as a contributing factor.

This statement led to a suggestion by one of the students that the *bottom* of the glass jar be heated to expand the air in the jar, allowing no flame inside the jar. In performing the experiment, the class observed that when the heated jar was inverted into the water, the water rose about 20 percent into the jar. Most of the class said that, in this case, the water rising had nothing to do with the "using up" of oxygen in the jar. They believed that in the case of the burning candle experiment, it was still possible that some of the rise was caused by the conversion of oxygen to the denser carbon dioxide as well as by the contraction of the cooling air. One student speculated that the solubility of carbon dioxide might be another factor.

### Conclusion—It Was a Motivating Experience

These elementary school teachers—as students—had experienced an opportunity to think! They had not been told the answer. Indeed, they found *conflicting* opinions in several "authoritative" textbooks. Their curiosities not satisfied, they sought a reasonable solution to the problem. They had opportunities to devise makeshift hypotheses and experiments (much as children in the elementary classroom do) without being criticized for being imprecise or crude with their methods. They experienced unhindered experimentation and learned to refine their own procedures. For the moment, at least, they approached the problem *scientifically,* rather than *prescriptively.* Moreover, efforts to seek the solution were held in high esteem by the class even when the "right" answer was not produced.

However, the teachers *did find* answers. Also, they gained insight in teaching science in the elementary school. Their exercise in scientific thinking helped them appreciate the value of providing similar experiences for their students.

By the way, why do *you* think the water rises in the burning candle "experiment"? Can *you* think of a way to prove it?

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[4] Joseph Glanz. "The Burning Candle Experiment." *The Science Teacher,* 30:29. November 1963.

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# An Experiment Never Fails!

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THE increasing number of institutes and curriculum studies concerned with both content and method reflect current attention on improving the elementary science program. Scientists and educators are attempting to write a series of developmental learning experiences through which children may progressively build scientific concepts, develop critical thinking, and experience the thrill of discovery. This will undoubtedly improve the elementary science program; however, these studies should give some consideration to training teachers in the proper use of scientific terms—*demonstration, exercise,* and *experiment.* Too often, clear-cut distinctions between these three basic operations used in teaching science are neither understood nor applied correctly by the elementary classroom teacher.

Elementary teachers, if we speak in general terms, are apprehensive about teaching science. An "experiment," as they understand and use the term, should be practical and made to work. Teacher failure is blamed on the lack of proper equipment or the use of improper equipment. Insufficient class time and lack of space is often used as a scapegoat. The pupils, as a result, must limit many of their science experiences to those outside the classroom.

The terms *demonstration, exercise,* and *experiment* are misued by undergraduate students fresh from science content courses. These terms are misused in graduate elementary science classes, misused in many of the children's textbooks that are currently coming off the press, and misused in science fairs by both the exhibitors and the judges.

This article is designed to clarify the meanings of these terms. The following points must be emphasized in their definitions:

An *EXPERIMENT* is a process of testing a hypothesis with no known results predictable.

You can practice giving a *DEMONSTRATION,* but you cannot practice an *EXPERIMENT.*

A *DEMONSTRATION* may fail, but an *EXPERIMENT* never fails, or for that matter, never succeeds.

An *EXERCISE* is neither an *EXPERIMENT* nor a *DEMONSTRATION*. An *exercise* in science is somewhat related to today's programed instruction; *i.e.*, most of the creative thinking, as well as the sequence of steps to be followed in an *exercise*, has been critically thought out by the writer of the instructional material.

During the past summer in a graduate elementary science workshop, a junior high school teacher was demonstrating (in the name of "experimentation") the effect of heat on the expansion and contraction of air. He was using a glass milk bottle, a hard-boiled egg, and a lighted candle. A fourth-grade teacher who was observing the *demonstration* asked, "Do you still do this 'experiment' in junior high school?" She continued by saying that she did the same "experiment" in the fourth grade. When the class of thirty-five students were asked if they used this particular *demonstration*, about half the students raised their hands. The milk bottle broke while it was being heated and the junior high teacher commented, "We won't be able to finish the 'experiment.' It did work when we tried it in our room last night. You know, milk bottles are hard to find these days."

Have we been in such a rut with our science program that we have limited our children to *one* and the same *demonstration* at several levels of instruction that we ourselves experienced years ago? If so, isn't it pathetic that it has taken the invention and social acceptance of the paper carton to enable us to see this dilemma and to change this so-called "experiment?"

If we are to communicate the thrill of discovery to children, we must also experience this thrill. The old cliché, *One cannot transmit what one does not have,* may emphasize this point best.

If the thrill of discovery that comes from *experimentation* will encourage a wholesome attitude toward science, the following suggestion may add a new dimension to elementary science teaching. With each group of *demonstrations* or *exercises* presented in the curriculum guides, the pupils should work cooperatively with the teacher to conduct at least one *experiment* of their own design.

It is a simple matter to set up a problem-solving situation to which one does not know the answer. Such an *experiment* will enable the teacher, as well as the children involved, to experience the thrill of discovery as the search for a solution develops. This *experiment* should be conducted at the developmental level of children, and it should augment the pre-planned curriculum that is being taught.

## Books Misuse Terms

To better grasp the significance of the present use of the terms *experiment, demonstration,* and *exercise,* let us cite a few currently used elementary science textbooks.

A 1962 elementary science textbook presents an *exercise* designed to teach a child how to make cloth fire-retardant. Ten statements tell the child what actions to take. Three statements explain to the child what is happening during the resulting action. One question is asked at the conclusion while six statements answer the question. This is referred to in the textbook as an "experiment."

A 1964 elementary science textbook uses a similar series of structured statements (an *exercise*) beautifully illustrated to help point out the answer to the problem under consideration. This, too, is referred to in the textbook as an "experiment."

A 1966 elementary science textbook refers to all *demonstrations, exercises,* and *experiments* as science activities. This textbook makes no distinction as to the different operations used in the teaching and learning of science or the respective values of the three activities.

In keeping with the foregoing suggestion as to the children's experimentation in the classroom, the following sequence may help one understand how the *experiment,* the *demonstration,* and the *exercise* may be unique operations and yet augment each other in the teaching and learning of elementary science.

**Experimentation** (the testing of a hypothesis with no known results predictable) should be carried on by the children and teachers to develop an interest in, a knowledge of, and an appreciation for the scientific method.

**Demonstrations** should be presented by the teacher to present a model of technical procedures and factual information that demand maturity, skill, or knowledge that the children do not have.

**Exercises** should be used to provide the practice necessary for the children to reinforce the conceptual learnings and the mechanical skills being considered. An exercise should also be used by both the children and the teacher for evaluation purposes.

Let us consider the above three operations as they relate to the problem of making cloth fire-retardant as cited previously.

1. The children discuss the problem of making cloth fire-retardant. They set up a hypothesis followed by *experimentation* with detergents, juices, and other simple home-oriented solutions to see if they have any effect on fire retardation. The use of simple laboratory chemicals should depend on the developmental age of the children.
2. The teacher *demonstrates* how to make cloth fire-retardant using proper chemicals and procedures.
3. The children are given an *exercise* similar to those currently being presented in children's textbooks as "experiments" to see if they can successfully utilize the learnings from the teacher's *demonstration* and their *experimentation.*

It is time that we stopped labeling our *demonstrations* and *exercises* as *experiments* and realize that each of the three teaching operations has a distinct place and purpose in the science program.

# Science Fairs? Why? Who?

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"WHAT'S good for high school science is good for elementary science!" Is it? The attention given to science fairs at the junior and senior high school level has led to current interest and emphasis in holding fairs at the elementary school level. This trend has forced elementary educators to consider the value of their use.

Opinions differ—as indicated by varying practices of "to have or not to have." Those who have not reached a conclusion would do well to recognize that the elementary science fair, if utilized, should (a) consider the nature and development of the elementary school child, and (b) should involve projects that serve the highest objectives of science education.

## Child Development

Studies suggest that the elementary child normally is curious and that his natural curiosity can be directed to "scientific investigation." A noted science fair coordinator says that:

> beginning science interests peak at age 12, with age 10 now coming a close second. Better than 10 percent of the nationally recognized students are launched toward a scientific future before they even enter kindergarten.*

Although some childhood interests flower early, we recognize the differences in developmental patterns. Also, we are aware that perhaps only a few pupils in a typical grade-school class may be science oriented. Some creative, talented children may not have the patience or persistence demanded by "scientific investigation."

A fair amount of guidance and direction for the child-investigator seems desirable, for the extent to which an elementary pupil can develop a project independently is questionable. The following criteria seem desirable when deciding if participation of children in a science fair is appropriate:

1. Only children with a genuine interest in a science project and with the initiative to see it to completion without undue adult prodding should be expected to participate in a science fair. A science project should never be an "across the board" requirement for a class nor a necessity for a good grade in science.

2. Any judging of a science fair project or display should preferably consist of helpful comments and suggestions rather than comparative ratings or prizes. If projects are assembled from an area, the emphasis should be on the stimulus of shared interests instead of competition between classes or schools.

## Suitable Science Projects

Suitable science projects are those which increase and direct a child's interest and competency in science. Worthwhile projects are those which are *problem-centered* and in which the *process* is important—not those which center on showmanship or gadgetry in display. Suggested below are categories of appropriate science problems for an elementary science fair.

### 1. Observation of the Environment

*What kinds of trees seem to grow best in our area?*

*What living things may be found in a cubic foot of garden soil?*

*How do some insects change as they "grow up?"*

These are the simplest types of problems, involving the study of the surroundings to classify and organize what is there.

### 2. Demonstration of a Basic Principle of Science

*How does electricity travel?*

*What causes erosion?*

*How does a machine make work easier?*

These are not really "research problems" where the answer is known before starting. Instead, their value is in enabling the student to express a clear explanation of a basic idea through his own understanding.

### 3. Collecting and Analyzing Data

*What is the average October weather like in our town?*

*What is the rate at which a pet drinks water?*

*How does the number of seeds produced by different plants compare?*

*Is there a relationship between the phases of the moon and the weather?*

In this type of problem there is no manipulation of nature by the student, but there is directed and recorded quantitative observations of things as they are. This is more specific than simple observation, which is merely descriptive. Here one may expect computation of averages, ratios, and rates; preparation of graphs and tables; and performance of other analytic processes.

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* Joseph H. Kraus. "A Reply to—Science Fairs and Cooperation." *Turtox News.* 42:10, January 1964.

**4. Controlled Experimentation**

*What is the effect of temperature on the activity of mealworms?*

*What is the effect of the moon phase on the germination of seeds?*

*What difference does the kind of wire make in the resistance of an electric circuit?*

This is the most valuable type of problem from the viewpoint of understanding science. It involves the use of controls—situations identical except for the one variable under consideration. Quantitative aspects are surely implied. It is apparent that the "answers" to some problems (e.g., "What difference does the kind of wire make?") are known to scientists, but they will be unknown as far as the children are concerned.

It is also quite possible that elementary children may come up with some original problems to which answers will *not* be found in the science text. In the execution of a project, children may make the valuable discovery that they do not have sufficient evidence for a valid conclusion. A science project which concludes: "This experiment does not show any relationship between A and B; more experiments are needed" may be as meaningful as one which comes to a remarkably demonstrable "answer."

Shall we have an elementary science fair? Only if careful consideration is given to the nature and the needs of students and to the objectives to be accomplished!

# Editorial . . .

The October issue of *Safety Education* carried the following items; Indiana, a science instructor struck a match to some rocket fuel on a playground as a demonstration to his students. A metal container exploded, and a little girl in a nearby physical education class was struck by a flying piece of metal. In California, a teenage boy was tapping matchheads into a 2-foot-long metal pipe in the living room while his friend held the "rocket." Suddenly, the rocket, stuffed with the heads from approximately 20 boxes of matches, exploded. The blast blew out the windows, started a fire, and hurled both boys a distance of 10 feet. One of the boys was severely injured and the other died on the way to the hospital.

## Know and Anticipate

Tragedies such as these should serve as a reminder to both teachers and parents that the safety lesson is never completely taught, and that the struggle to anticipate what children might do is as important as supervising what they are doing.

At this time of the year, it is especially important to consider the topic of safety in the elementary school classroom. Many of your students will receive gifts of chemistry sets, and other types of scientific toys and kits. Most of the manufacturers of these sets, kits, and toys have taken every precaution to remove all of the dangerous elements from these materials. However, there are other sources that the students can turn to for information on experiments and demonstrations that may prove harmful. Many libraries contain books and magazines that have "how to do it" articles which are actually unsafe in the hands of children and most adults. Another source of information for all elementary school children is the "word of mouth" source, which leads to the "let's try and see if it works" method.

While all areas of the school have potential hazards, and all teachers need to be safety-conscious, science is a subject that requires extra vigilance and special types of precautions. A part of all science teaching should be not only teaching safety but energetically building it into the science program.

We are all aware of the obvious dangers in the teaching of science; but carelessness, recklessness, ignorance, overenthusiasm, and the lack of proper respect for potentially dangerous forces like electricity, power tools, and radiation should also be considered. These hazards must be foreseen and controlled or avoided.

In the elementary school, one of the biggest dangers is the demonstration that the student "did at home" with his parent and now wants to put it on for the class. Often the demonstration is not even related to the topic being studied, but is spectacular. Many times the student only knows how to follow directions, without any understanding of the underlying scientific principles involved. If something goes wrong, he does not know what to do to correct the situation, or he gets hurt because "this never happened before." Never allow a student to demonstrate anything unless you have checked it out to see that it is safe. If you are not sure, consult a college or high school science teacher. If one of them cannot help you, it would be wise not to allow the demonstration to be performed. Remember, if you are in doubt, do not allow the demonstration to be performed.

"Safety is one area where 'open-ended' experiments and a laissez-faire attitude are NOT in order. The facts are known; observe them." *

FRANK R. SALAMON

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* Mary Hawkins, "TST Forum." *The Science Teacher*, 31:53. September 1964.

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# *Miniature Terrariums*

My elementary school is engaged in an experimental program designed to provide curriculum enrichment for culturally deprived youngsters. The "More Effective Schools Program" furnishes the children with specialists in health education, science, music, art, and speech. It is vital for the slow or the disadvantaged child to work with materials. This is necessary for any child, but even more so for youngsters who may have a language handicap. Many language-handicapped children display manual dexterity and insight in working with materials while youngsters gifted with glib tongues sit by completely stymied.

One imaginative way to motivate and stimulate the slower children's interests is to have them prepare and study a classroom terrarium. A terrarium may be defined as a glass-enclosed garden which contains only plants or both plants and animals. To city children, it may serve as a window through which they will study nature closely for the first time. It will show children the basic principles of ecology—the interdependence of plants and animals within a small community. The terrarium can serve also as a "greenhouse" for raising large numbers of plants which can be used for classroom experimentation.

Plant study can be exciting in a classroom. Many teachers in elementary school shy away from experimentation with plants, because they think the results are too slow for children. Watching large plants grow from the leaf cuttings of piggyback plants, African violets, or snake plants and from stem cuttings from coleus, geraniums or philodendrons is just as exciting for youngsters as observing the growth of baby guppies.

Three common types of classroom terrariums are woodland, semi-aquatic, and desert. In order to determine which type of terrarium is best suited for your classroom, consider the varieties of plants and animals available to you and the difficulty of growing and caring for them. At least two different types are desirable in each classroom to best point out the differences in the natural habitats of various plants and animals. This can be very effectively correlated with social studies to show how geographical barriers and topography determine both the weather conditions and dominant life in an area.

The material and procedure for assembling a miniature woodland terrarium are described below:

### A Woodland Terrarium

**Animals:** common newt, toads, wood frog, slugs, snails, beetles, sowbugs, caterpillars, grasshoppers, and praying mantises.

**Plants:** wild ferns, liverworts, mosses, lichens, creeping snowberry, partridge berry, and evergreen plants.

Almost any kind of wild flower or tree seedling native to wooded areas will thrive in the terrarium. Many house plants will live in its warm, humid atmosphere also. In addition, the woodland terrarium can be used to root cuttings and to germinate seeds.

**Materials:** gravel, glass container, crushed charcoal, soil, and a piece of glass or plastic.

**Procedure:** Put an inch or two of gravel in the glass container—a large jar, a fish bowl, or a brandy snifter. It will serve as a reservoir where excess water can be stored. Next, place your crushed charcoal (barbecue briquettes will do) into the container. This sweetens the soil to insure good plant growth. Then add two or three inches of soil (potting soil or soil from wooded area) over the charcoal. Cover the soil with moss or green-colored gravel. Next place your plants in carefully without overcrowding. Let the size of the container you use determine the size of your plants. The last step is to cover your terrarium with a glass cover or plastic. This keeps the moisture in your garden and eliminates constant watering.

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# Aquarium Questions

One of the most neglected devices for teaching the discovery approach in the elementary classroom is the *aquarium*. Many of these aquariums are used only for decorative purposes in the classroom; although they offer the teacher many opportunities for instilling the discovery approach in students.

Directions for setting up an aquarium may be found in any one of the many source books for elementary science, or the March 1962 issue of the *Elementary School Science Bulletin,* page 5.

For early elementary grade students, the authors recommend that two large goldfish be kept in the aquarium rather than several smaller varieties. The larger goldfish can be observed and studied more easily by the students.

Once set up, the aquarium should not be placed in a corner of the classroom and forgotten. This is the time to help the students make observations and discoveries about the fish, plants, snails, and water. What are some of these observations that students can make?

## Questions from Fish

All animals have some means of locomotion; this is observable in the aquarium as the fish swim about. But how do the fish get from one end of this glassed home to the other? Do they use their tails in any way? How do they turn around or slow down? Do they use their fins for any purpose?

Are the fish similar to other animals that the children are familiar with? If not, how are they different? A large fish, purchased at the local fish market will afford the students an opportunity to study and examine the large external parts of the animal. The students will be able to see the gills in relation to the gill covers. The placement of fins and body covering could also be studied by the students. If a microscope or microprojector is available, a fish scale can be examined in detail. The age of the fish may be determined by counting the growth rings on the scale. (One year for each ring.)

A discussion of how fish breathe could be followed by observations of the fish in the aquarium. Are their nostrils used for breathing or smelling? Where do the fish get their air for breathing? What steps have to be taken if the fish keep coming to the surface of the water in the aquarium? Observing the eating habits of fish may lead to many interesting learning situations.

What experiments can be devised to find out if fish hear vibrations? How can members of the class find out if fish make sounds of any type? (This topic may require library research.)

## Questions from Snails

Snails in the classroom aquarium may be a new experience for your students and a fascinating one. These creatures are different from other animals that may be familiar to the students. Compare the aquarium snail with a land snail. If time permits, the snail may be compared to the slug. For our purposes the slug may be described as a snail without a house on its back.

Does the snail move from one place in the aquarium to the other in the same manner as the fish do? If not, how does this animal move? Place the snail on a piece of glass and hold it above the student's head so he can observe the snail's locomotion. The shell of the snail is very interesting. Does it offer the snail any protection?

Have the students observe the snail's eating habits. Where is the mouth? What food do snails eat? The students' observations of the snail on the glass, mentioned above, will help them to locate the snail's mouth. Do the snails eat worms, or are they vegetarians? Are the tentacles located on the snail's head used for feeling? Do they have eyes? Using a ruler and watch, have the boys and girls compute the rate of speed the snails travel a certain distance. Have them do this experiment more than once and plot graphs based on the evidence collected.

### Questions from Plants

There are at least four common types of plants which may be kept in the aquarium very successfully. Duckweed is a small plant which floats on the surface of the water. This plant appears as tiny leaves joined at one point with small roots extending into the water. Fish will enjoy eating this plant. Vallisneria is a long-bladed grasslike plant which may be rooted to the bottom. Elodea, a semifloating plant with short broad leaves growing directly and closely from a central stalk, is a good oxygen producer. Cabomba is another floating plant with five needlelike branching leaves. Snails and fish will nibble at both elodea and cabomba.

What would happen to these plants if they did not receive any light? Place a plant or two from the aquarium in a jar of water and store it in a dark closet for a week or two. What happened to these plants? Do the fish and snails eat the plants? At times the pupils will see bubbles form and rise from the leaves of the plants. What are these bubbles made of? Are these bubbles similar to ones they can see in a glass of water that has been allowed to stand in the sunlight for some time?

By using the aquarium in this way the students can be led to many interesting discoveries on their own. It is not necessary for the teacher to know all of the answers to the questions which will come up from a study of the aquarium, but it is important that she be interested in helping the students find the answers by observation, experimentation, and reading. If this approach is used in teaching science, the students will learn many science concepts and also acquire some information about the process of scientific inquiry.

# A Saltwater Aquarium

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ALTHOUGH more than seven tenths of the surface of the earth is covered by water, most of us know surprisingly little about the oceans. That the seas, oceans, and lakes have a great deal to do with our daily and future existence cannot be overemphasized. As an illustration, congressional studies on the significance and role of oceanography have described reasons for the study and development of oceanography such as:

The need to develop, through survey and study, biological and mineral resources of the sea;

The need to develop new knowledge about the sea, since contemporary events make scientific achievements an element of public affairs;

The need for more basic information concerning the origin of Earth and the evolution of life itself; and

The need to develop information about the safe disposal of radioactive wastes.[1]

This proposed development of oceanography will not come about without stimulating students to enter the field. This responsibility rests with educators, who must work to increase the opportunities for study of the seas.

How can oceanography be studied in the elementary school classroom? A teacher and her students can follow the newspapers and search out the increasing amount of articles in periodicals. However, a better way to bring the seas closer to an elementary classroom is to establish a saltwater aquarium.

Barbara Neill of the American Museum of Natural History, Department of Education, Science Education Center, New York City, has been very successful in maintaining a saltwater aquarium on a year-round basis. From Miss Neill's directions and the author's experience with classroom aquariums, the following instructions are recommended for preparing a saltwater aquarium.

Anyone who has kept freshwater

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[1] "Ocean Sciences and the National Security." House Report #2078. U. S. Government Printing Office, Washington, D. C. 1960. p. 2-4.

aquariums successfully will find that maintaining a marine aquarium is not as difficult as usually believed. The basic rules for keeping freshwater aquariums apply even more strongly to marine tanks—don't overcrowd, remove uneaten food promptly, and make sure that water conditions are suitable.

### Container

Since no metal of any kind should be in contact with the saltwater, a rectangular tank made completely of glass or plastic is best. Such tanks may be hard to find, so an ordinary metal-braced, glass tank can suffice. (Remember that even though the frame is stainless steel and not directly in contact with the water, the metal will eventually rust.)

### Water

Natural ocean water is best, especially for invertebrates such as sea anemones or starfish. Commercial aquarium salts, mixed according to directions, seem satisfactory for many fish. Pure crystal salt with no additives can be used, provided a small amount of real seawater is added.

In order to know how much salt the water contains, a hydrometer is necessary. This simple, inexpensive glass float has graduations to mark the water level according to salt concentration. It should float at, or slightly above, the red line marked 1.025%. Since water is continually evaporating from the aquarium, the proper salinity must be maintained by occasionally adding pure *freshwater*. It is better to have too little salt than too much.

Keeping the water cool in a classroom aquarium can present a problem. One solution is to maintain the aquarium only during the colder months. Simply place the aquarium near a partly opened window with one side of the tank in contact with the cold air. The seawater temperature should range within 50-65°F.

### Equipment

The water in a marine tank must be continually aerated and filtered to maintain sea life. Purchase an air pump powerful enough to operate several filters. Inside filters with charcoal or calcite in the bottom and glass wool above are most satisfactory. Outside filters are risky if you keep large, active animals (blue crabs or whelks) because they can direct the return flow of an outside filter out onto the floor.

Be sure the filter is adequate for the size of the tank. Most ocean life is adapted to constantly moving, oxygen-filled water—in contrast to the stagnant water of little pools or quiet rivers, which supports many of the commonly kept freshwater fish.

### Sand, Plants, and Rocks

One or two inches of cleaned beach sand adds to the attractiveness of the tank besides providing cover necessary for some inhabitants. Caves and crevices (created with rocks) will be used by some species of fish. Sea horses will "anchor" themselves to coral.

Except for the attractive green algae known as "sea lettuce," don't put plants in your marine tank. Some ocean plants become toxic when they die; most are brown or yellowish even when alive, so dead plants are often not removed soon enough to prevent fouling the water.

### Stocking the Tank

If you are near salt water, why not consider collecting some marine specimens for your own tank? Take plastic or enamel pails, nets, and a small container for sorting the contents of the net to a beach at low tide. Choose only a few, small specimens of each species. It is better to come home with 3 small fish, 2 hermit crabs, and 1 little starfish alive and healthy than 10 fish, 15 hermit crabs, and 6 big starfish—all either dead or dying. Put the sea animals into large containers filled with sea water. Be careful that the water does not become overheated. When introducing specimens into the tank, be sure there is no change in water temperature.

Although what you catch depends upon locality, season, tide, and chance, the animals most often collected are: killiefish, pipefish, sculpin, eels, hermit crabs, baby horseshoe crabs, green crabs, scallops, mussels, mud snails, periwinkles, whelks, starfish, barnacles, and sea anemones.

Pet stores sometimes stock sea horses, porcupine fish, trunk fish, butterfly fish, and other strikingly beautiful marine animals.

Most ocean animals are carnivorous, so a "community tank" must be assembled carefully. Introduce only very small specimens of aggressive species.

### Maintenance

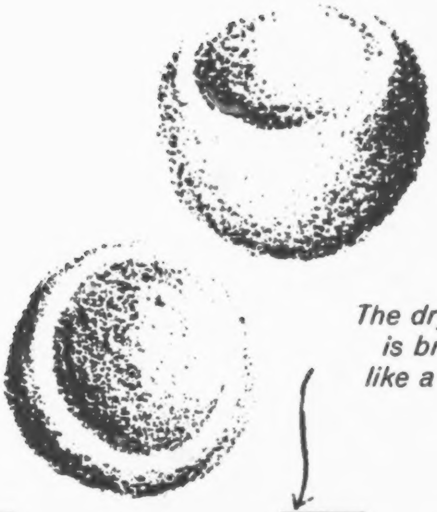
Proper feeding takes a little time. A pinch of dry food sprinkled on the surface of the water will not do for a marine tank. Some species of fish will die unless fed live food. Others, such as sea horses, are so slow-moving that they will starve if kept with larger and faster species. Live food, such as tubifex worms, daphnae, bloodworms, and brine shrimp, is usually available in pet stores. Chopped liver, beef, raw fish, or chicken will satisfy species not requiring live food. Add food daily, making sure that enough falls to the bottom for the scavengers. Hermit crabs, mud snails, and sand shrimp eat a surprising amount.

If filters are cleaned regularly, the inner surfaces of the tank wiped clear of algae, and the water level maintained, there seldom should be need to empty the tank unless it springs a leak.

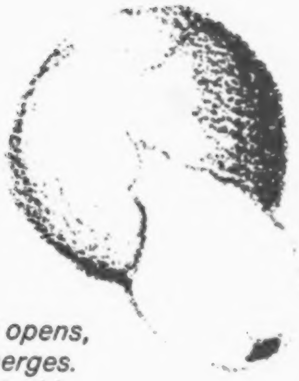
Be alert to the health of all inhabitants. Shellfish, especially clams, oysters, mussels, and slipper shells, must be observed carefully for signs of life. Should the water become cloudy, search for the probable cause; take out any uneaten food or dead animals.

A section of half-inch plastic tubing can be used as a siphon to remove food or any other debris. Cloudy tanks can often be cleared by installing one or two extra filters. Extra salt water should be kept on hand to replace that lost when filters are changed and dirty water is siphoned off. Store this extra water in clean glass containers.

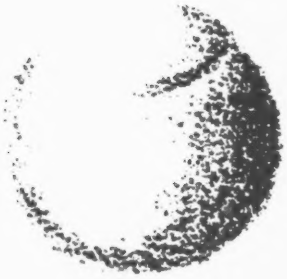
# From Egg to Shrimp in 30 Hours



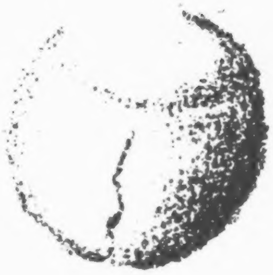
*The dry brine shrimp egg is brown and shaped like a teacup—concave.*



*When the shell opens, the shrimp emerges. It is enclosed inside a thin clear sack.*



*After the egg has been in solution a short while, it fills out and becomes round as a ball. The deep circle around the egg is formed from the "teacup" rim when dry.*



*As the egg develops, it begins to crack from one side to the other, and is stopped on each side by the deep circular impression.*

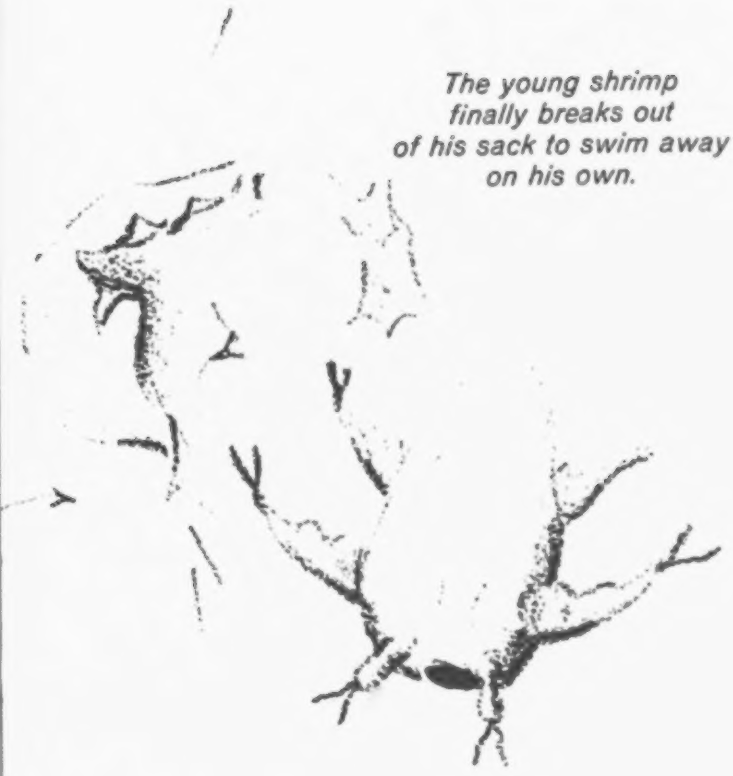
**LeROY MOORE**
Instructional Consultant
Duniway Elementary School
Portland Public Schools
Portland, Oregon

Children of all ages enjoy watching the development of living things. Teachers often shy away from activities which involve living things because of the time, care, and equipment usually required for this type of unit. The activities described in this article can be used in grades K-6 and require little space and a minimum amount of care.

One of the most fascinating, easy to raise, and easy to care for creatures in any classroom is the brine shrimp (*Artemia salina*). The eggs of the brine shrimp can be purchased from most pet or hobby shops that sell tropical fish. (If you cannot obtain the eggs locally, write to Sanders Brine Shrimp Company, 800 Washington Blvd., Ogden, Utah.)

### Preparation of Materials

Brine shrimp can be hatched in almost any clean, wide-mouth container. (A quart fruit jar is most satis-



The young shrimp finally breaks out of his sack to swim away on his own.

factory.) Dissolve 1½ tablespoons of noniodized salt into a quart of water. Try using well, pond, or ditch water. If this is unavailable, use tap water that has been allowed to stand for at least 24 hours. This allows the chlorine content to dissipate. Next, pour enough eggs onto a piece of paper to cover a circle ¼ inch in diameter and then place the eggs in the prepared water. The prepared container should be placed in a location where the temperature is somewhere between 60° F and 90° F; 85° F is usually the ideal temperature. After 24-48 hours, place the container near a bright light. You will have to look carefully to see the brine shrimp since they are very tiny.

### Keeping the Shrimp Alive

The following suggestions will prove to be helpful in promoting the life span of brine shrimp:

1. After 48 hours, most of the brine shrimp will have hatched. About ten shrimp is all that a quart jar will accommodate. Thin out the excess with an eye dropper. An excessive amount of shrimp will cause them to suffocate for lack of oxygen.
2. Feed them once a week with a small pinch of dry yeast.
3. Try to avoid sudden changes in temperature.

### Suggested Activities

1. Draw some of the shrimp into an eye dropper. Observe them with a hand lens. Have the children describe their motion.
2. Allow the children to suggest or develop methods for comparing the size of the shrimp from week to week.
3. Observe some dry eggs under a microscope or a hand lens. Make notes and pictures of any unusual details; e.g., the shape of the top of an egg (teacup shaped).
4. Observe the living shrimp under a microscope, a microprojector, or a hand lens. Ask the children to make notes and drawings of what they see.

### More To Do

Ask the students to predict what will happen if they:

1. Vary the amount of salt to be used in the hatching.
2. Freeze some of the brine shrimp eggs in ice before trying to hatch them.
3. Try hatching the shrimp without salt. Five days later add the proper amount of salt and observe the eggs six hours later.
4. Blow your breath through a straw and into the water containing some brine shrimp for about five minutes.
5. Add four or five drops of vinegar to the water containing living shrimp.
6. Add some baking soda to the water containing living shrimp.
7. Use different shaped jars as containers in hatching the shrimp (some wide mouth and some narrow mouth).
8. Try hatching some eggs in a light place and some in a dark place. (Compare time required to hatch the eggs in both locations.)

### Thought Questions

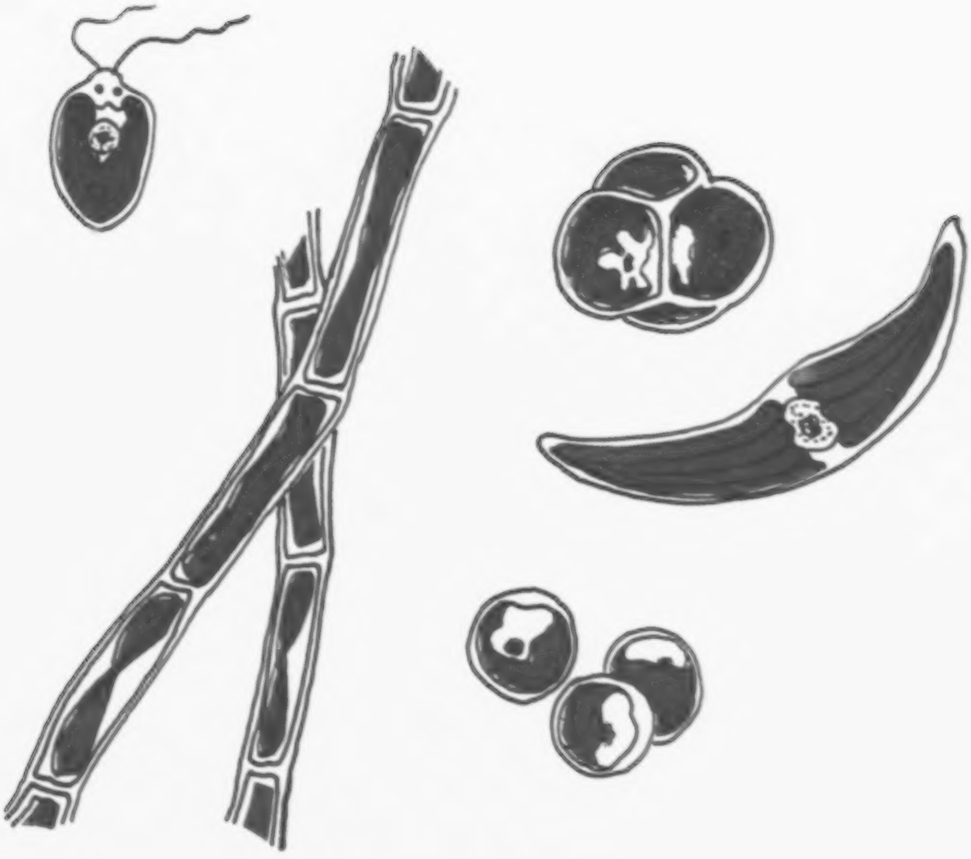
1. Can you make the eggs hatch without water?
2. Will all the eggs hatch?
3. Why do brine shrimp grow better if you put algae (tiny green plants) into their water? Note: Algae may be found in ponds.
4. Do the shrimp keep moving night and day? Why?
5. Where can one find brine shrimp or brine shrimp eggs in their natural environment?
6. Why will brine shrimp gather near a light? (Place a light source on one side of a container.)

### Suggested References

Carleton Ray. *The Adventure Book of Underwater Life.* (Intermediate.) $3.95. Golden Press, Inc., 630 Fifth Avenue, New York City 10020. 1959.

Katherine Carter. *The True Book of Oceans.* (Grades 1-4.) $2. Children's Press, Inc., Throop and Monroe Streets, Chicago, Illinois.

Ferdinand C. Lane. *All About the Sea.* (Grades 4-6.) $1.95. Random House, Inc., 457 Madison Avenue, New York City 10022. 1953.



# ALGAE

# –A Hidden Teaching Resource

**JAMES W. COX**

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THIS fall your class could enjoy working for a few days with the most primitive of all plants—the algae. Although algae are seldom exploited as a teaching resource in elementary science, these simple organisms offer excellent material for studying plant cells and the interactions of plants with the environment.

Algae are living material which can be collected easily by students, especially during the warm months. No other plants that can be brought in by the students themselves can yield such convenient lessons in taxonomy, cytology, and ecology as the algae. With relatively little magnification, the infinite diversity and beauty of microscopic algae can be discerned. You may find these plants are very effective in creating a reverence for life in your students—certainly an important goal in science instruction.

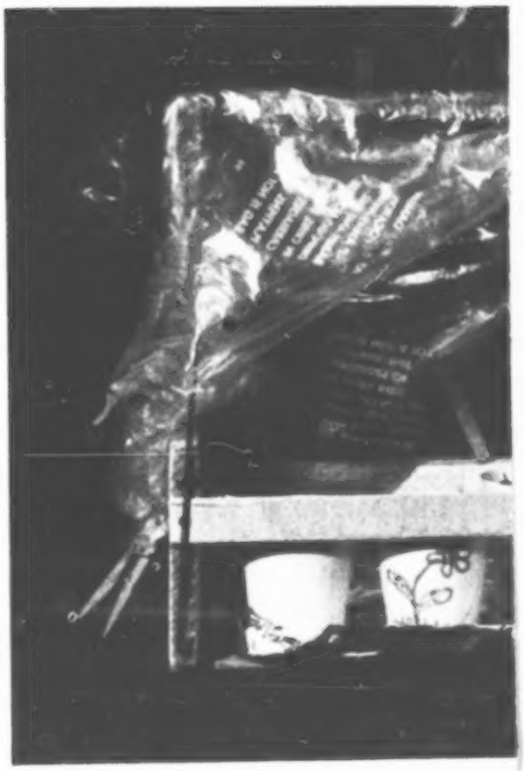
Algae are so plentiful in the environment that your students can probably gather many different types of freshwater algae within a few hundred yards of your classroom. The children may have difficulty in distinguishing algae from other water plants when collecting samples. A general rule they can follow is: If the plant is large enough to have distinguishable stems or leaves, it is not an alga; if it appears to be green slime, it is probably algae! Greenish, stagnant water, bird baths, ponds, aquariums, stock watering tanks, streams, even puddles will all offer some species.

Have the students gather small amounts of algae in jars (including samples of the water). They should keep each sample in a separate jar labeled with the location where the algae was collected. Since some forms of algae "cling" to rocks, culverts, and submerged plants, the children should investigate these surfaces while collecting.

An elementary study of algae calls for few materials: a microprojector or microscope (10X-100X is adequate magnification), several medicine droppers, slides, and cover glasses.

In preparing the algae for the microscope or microprojector, remember to take a very small amount of material. Too many fibers on a slide will produce a confusing, opaque mat. A few fibers, or a greenish drop from the jar, will suffice. Place the specimen on the slide and then add the cover glass.

With the algae focused under the microscope, the students can identify the various genera. There are several sources to consult in identifying algae. Encyclopedias and col-



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**OLIVER A. BATCHELLER**

Ornamental Horticulture Department
California State Polytechnic College
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At the primary grade level, planting seeds and watching them grow is an effective classroom activity in nature study. The simple task of keeping seeds planted in good soil, watered and warm, is easily mastered by these young pupils. With each seedling that appears and grows, the students can observe the relationship of the results of an experiment with the quality of the procedure in performing it.

In order to insure germination and provide a place where the seeds and plants can be encouraged to grow, a controllable climate is needed. A classroom-made greenhouse can be constructed to serve this function by using the following methods and materials:

**Materials:**

Fruit crate, metal coat hangers, plastic pots, cleaners' plastic bags, plastic bleach container, broom handle, nails, straw, sandpaper, and clothespins.

**Construction:**

1. Saw the sides and bottom off the fruit crate as close to the end boards as possible. This will prevent splitting the thin boards, and will make it easier to remove the nails.
2. Use two pieces of wood, 7½ x 4½ inches, for the ends of the greenhouse.
3. From the thin boards, cut two side slats 15 x 2 inches, and one or two slats 15 x 7½ inches for the bottom. Smooth the sides with sandpaper, particularly the corners to prevent tearing the plastic when it is placed on the frame.
4. Now assemble the greenhouse as shown in Figure 1. If you wish to paint it, latex paint is quick drying, easy to handle, and not affected by moisture.

The miniature greenhouse will accommodate eight disposable plastic pots. Even with plants, it is light enough for a primary student to handle. At this point, appoint one of the students as *Horticulturist* to be in charge of the plants.

When the construction of the greenhouse is completed, contact a member of the American Association of Nurserymen, a member of your state nursery association, or the Agricultural Research Service for information on the plants that grow best in your area. These resource people can tell you how long it will take for the seed to germinate and when the new plants will be big enough to take home and set out. In this way, you can schedule your project for a given date—"Mother's Day," for instance. For cities, where yard space is at a premium, have your nurseryman suggest plants which can be grown in pots indoors. At the nursery, you can obtain good seed, soil, and 3-inch plastic pots. The plastic pots are attractive, light in weight, inexpensive, and easily decorated by elementary school students.

**Planting:**

Make at least four holes in the bottom of each pot with the point of a pencil. Then fill the pots with soil, leaving from ⅛ to ¼ inch of space at the top. **(Do not press the soil into the pot.)** The soil settles, and about a ⅜-inch space is left at the top.

In general, three to five seeds evenly spaced in each pot are enough. Cover the seeds lightly with sand, not to exceed two times the diameter of the seed. Place the pot in a pan of water and allow the soil to absorb water until the moisture shows in the top. Remove and allow to drain for 10 to 15 minutes.

Make a shallow pan of metal foil (double thickness). Cover the bottom of the pan with straw and place it in the greenhouse. Put the seeded pots on the straw and cover the greenhouse with a plastic bag. Since the plastic of the cleaners' bag is so thin, use it doubled. Put the center of the bag over the broom handle and tuck the ends under the bottom of the greenhouse. Close the sides tightly with clothespins or paper clips.

Now, place the greenhouse in a warm (60° to 70° F) but shaded location until the seeds begin to break through the soil. As soon as sprouts appear, put the greenhouse in a window where the seedlings will get full light. Direct sunlight is desirable. Have your horticulturist turn the greenhouse around each morning so that all plants get equal lege textbooks usually have colored charts showing common algal forms. The United States Public Health Service offers an excellent pamphlet, "Algae in Water Supplies," * which contains many colored illustrations of the different algae.

More important than identifying types of algae by name, however, is the observation of cell structure. In the microscope, students can see very clearly the cell walls of different shapes, characterizing the different forms. In many algae, also, they can observe the intricate and beautiful patterns of the chloroplasts—the bodies within the cell walls containing chlorophyll. The children may discover that they have collected some algae that are single-celled, some that form spherical colonies, some that are long strands of barrel-shaped cells, and some that branch. A greenish drop of water may even contain some protozoans which can be examined and identified. If the pupils should discover a single-celled organism containing chloroplasts moving about in the drop of water, it may be *Euglena*. This microorganism contains chlorophyll as all green plants, but moves about like an animal. Some scientists classify it as a plant, others call it an animal.

If the students make careful observations of their samples from different locations, they will find that different environments favor different kinds of algae. Cool, running water and warm, stagnant water, for example, will favor completely different genera.

Another feature to recommend the study of algae is the convenience of storage. Algae lives well in a cool, shady spot. The refrigerator, of course, would be best; but a window sill is fine in cool weather. The algae can be set aside for a week while the children learn more about these simple plants from references and class discussions. Algae will be even more fascinating when examined the second time!

*Algae is plentiful in the environment, and students will be able to collect samples in many different places.*

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* "Algae in Water Supplies." U. S. Public Health Service Publication No. 657. U. S. Government Printing Office, Washington, D. C. 20402. $1.

# Animal Movement

**ROBERT PATTERSON**

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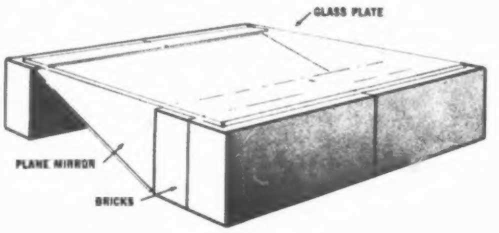
Animal movement can be effectively explored at the lower primary grade level by an inexpensive, yet unique, method of presentation. The procedure follows the style of the Elementary Science Study experiences. The device needed is simple to construct and easy to store. It consists of six bricks; a flat, clear-glass plate; and a large plane mirror. See Figure 1. In use, several of these units can be spread about in the room. Have the students place sow bugs, ants, and then earthworms on the glass plate and observe each animal's movements from above and below (reflected in the mirror).

FIGURE 1.



Observations that produce thought and excitement might include comparisons of the locomotion of lizards and tree frogs. Small snakes placed on the glass plate are especially interesting for this type of study.

If the glass plate is moistened with just a small amount of water, snails can also be observed. Pupils can watch how snails overcome obstacles such as marbles, rulers set on edge in a small mound of clay, or thin layers of gravel and sand.

Stimulated by the excitement of discovery, the students will explore more types of animal movements.

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amounts of light and grow straight.

If the classroom is not too hot and dry, the plastic cover can be removed or loosened. Watering should not be necessary until about a week after the seeds sprout. If seedlings are very small, the first watering should be done by setting the pots in a pan of water.

As the plants grow and the leaves become larger, you may have to water once every four days. A good rule is to water thoroughly but infrequently. Never allow water to remain in the foil pan, for this will cause the soil to become oversaturated and root growth will be retarded.

Your nurseryman may suggest some anti-fungus material to add to the water. After the seedlings are growing, he may suggest some fertilizer which can also be added to the water.

Two weeks before the plants are to go home, they must be "hardened off." This is to acclimate them to the conditions under which they will grow outside. This will mean putting them near an open window or outside during the daytime.

When transplanting, to remove a plant from the pot, put your first two fingers gently around the plant and tip the pot upside down. Now tap the edge of the pot. The plant groups should slide gently out of the container and into your hand. Carefully divide the groups of plants keeping as much soil around the roots as possible and replant them. Be sure to water the new seedlings thoroughly, and if possible, shade them for one or two days.

### Additional Ways to Make This Project More Meaningful to Students

1. A week or two before your project starts, fold or roll a paper towel, moisten it, and seal it in a clean glass jar with a little water in the bottom. Each day add a few seeds in different folds of the paper and replace it in the jar. By the time the project starts, you will be able to show your students seeds in various stages of growth. You should also be able to show the thousands of fine root hairs, through which the plant absorbs most of its water and mineral nutrients.
2. When the seeds in the pots germinate, you can show the force of plant growth as the shoot pushes up through the soil.
3. On Mondays, you can call the students' attention to the way the plants have grown toward the light over the weekend.
4. Some seeds can be planted in sand and not fed to show the importance of feeding plants.
5. One pot can be covered with a plastic bag and left that way to show how plants grow in high humidity (or moisture).
6. One pot can be left outside to show the effect of the temperature.
7. One pot can be left in a dark room to show how weak, spindly, and pale plants become when there is insufficient light.

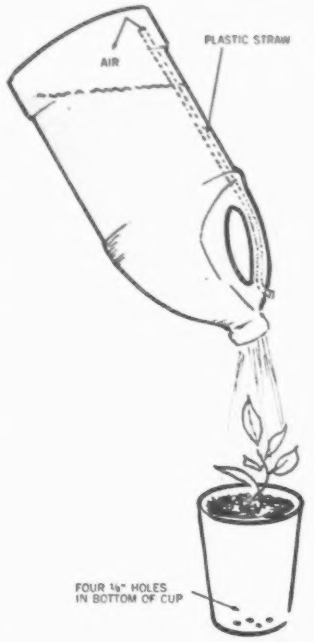


FIGURE 2.

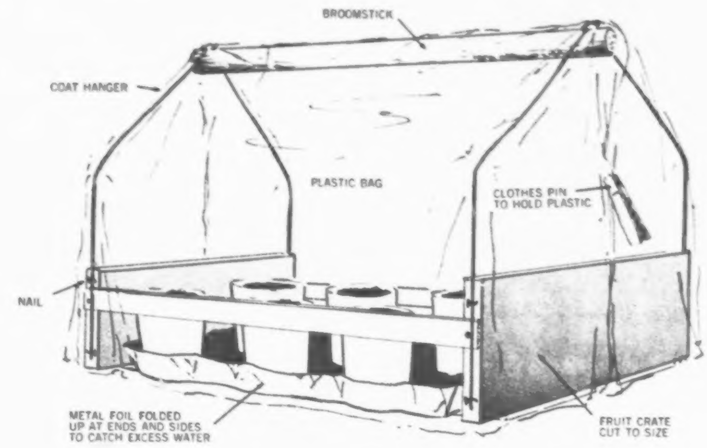
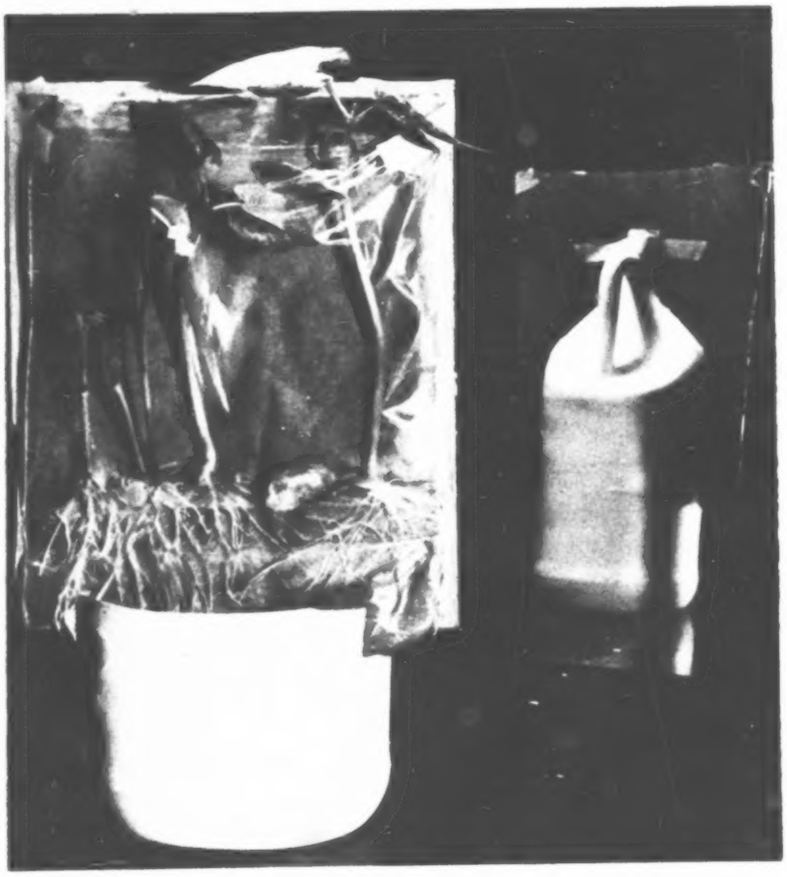

BROOMSTICK
COAT HANGER
PLASTIC BAG
CLOTHES PIN TO HOLD PLASTIC
NAIL
METAL FOIL FOLDED UP AT ENDS AND SIDES TO CATCH EXCESS WATER
FRUIT CRATE CUT TO SIZE

FIGURE 1.

A bleach container can be used as a squeeze bottle for water. A plastic drinking straw can be used as a breather to allow the water to flow evenly. With a hot nail, burn a small hole in the top of the handle of the container. Insert the straw into the hole until only ⅛ inch remains out and then seal the joint with rubber cement or waterproof glue to make it watertight. See Figure 2.

Punch several small holes in the cap of the bottle so the water will escape in a spray.



# Germination Chamber

**JACK GRUBE**

Science Teacher
Andrew Hill High School
San Jose, California

Here is an easily constructed seed germination chamber that offers several advantages.

*Materials:*

One ½ gallon, plastic, bleach bottle, sandwich size plastic bag, cellophane tape, rectangle of 3/16-inch plywood or similar material, and paper towels.

*Construction:*

1. Cut out the plastic bottle as shown in Figure 1. (A hacksaw and scissors will do the job.) The prepared bottle will serve both as a stand and as a reservoir for water.

2. Cut the bottom from a plastic bag to form a tube. Fold the paper towel to form a strip as wide as the bag and two or three inches longer. Slip the towel inside the bag so that it is even with one end of the bag and extends out of the other end.

3. Fasten the bag and towel to the plywood with cellophane tape. Place one strip of tape across the center of the bag. This will serve to keep the seeds in position. (See Figure 2.)

4. Seeds can then be placed along the center line of the germination chamber. The tape along this line should be adjusted so as to be tight enough to keep the seeds from dropping through but allowing room for the roots to penetrate downward.

5. The top of the chamber can now be taped in place but left open to allow room for growth.

6. Fill the plastic bottle with water and put the germination chamber in place with the exposed towel in the water. The towel will act as a wick and supply water to the seed.

The germination chamber is advantageous because (1) It is a self-contained unit that can be displayed at any convenient place in the room. (2) The student has an unobstructed view of the entire developing seedling. (3) It can be easily removed from the stand and placed flat on the table for examination. (4) The developing plant structures can be measured and examined under magnification without removing them from the chamber. The chamber can then be returned to the stand for further development.

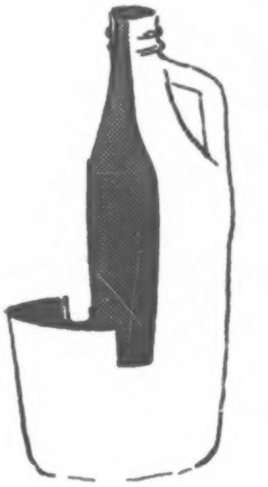


FIGURE 1.

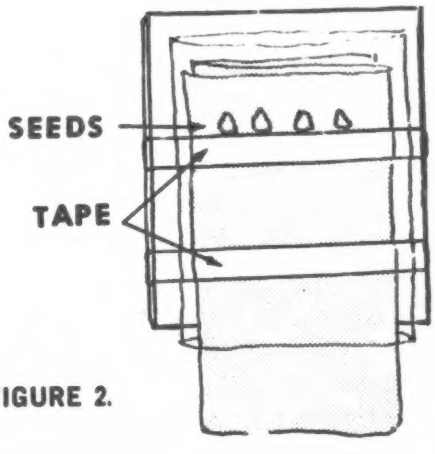
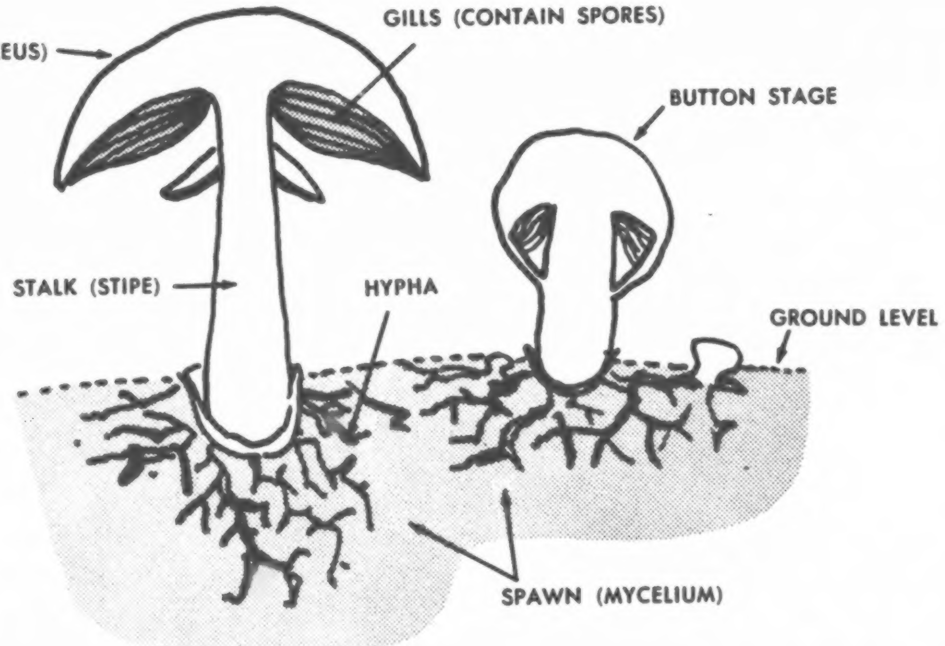


FIGURE 2.



# Fungi as Teaching Tools

**J. DAVID LOCKARD**

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University of Maryland, College Park, Maryland

Of the thousands of plants that the elementary teacher might raise in the classroom, some of the easiest to cultivate are the fungi. These filamentous organisms reproduce typically by means of microscopic bodies called spores which function as a kind of seed. Because of their small size, the spores are easily air-borne; and when they alight on moist substances of the proper temperature, they may start to germinate or grow. If they can take nourishment from the substance on which they rest, they may grow very rapidly, and in a short period of time become visible to the unaided eye. The white cottony filaments, which can be seen without a microscope, are known collectively as mycelium and individually as hyphae (plural, hypha).

Fungi have no true roots, stems, or leaves and since they contain no chlorophyll, they are as dependent upon green plants for life as are animals. They get their nourishment from organic materials either as parasites (if the material is living) or as saprophytes (if the material is dead). This is the reason fungi are frequently associated with agents of decay or destruction. It is true that the mildews, rusts, and smuts are quite harmful to other plants. Equally true is the fact that life, as we know it, could not exist if it were not for the ability of some fungi and their relatives, the bacteria, to breakdown the mass of dead or dying organic material on earth.

A number of fungi contribute generously to man's well-being. The yeasts are known for their role in bread-making and in the production of alcohol, the highly important commercial solvent. Certain fungi produce antibiotics such as penicillin that help cure some of man's illnesses. The cultivated mushroom, *(Agaricus bisporus)*, not only adds flavor to our meals, but is also a good source of proteins and vitamins. Recent research with fungi has uncovered an anticancer factor, *calvicin*, in the puffballs and a tension-relieving drug, *psilocybine*, in the hallucigenic mush-

*The natural curiosity of these elementary school students is aroused as they examine the meadow mushroom (left) and the forest mushroom (right).*

rooms from Mexico. These are just a few reasons why the fungi need to be better understood by our young people as well as by adults.

### Classroom Experiences

Listed below are a number of simple experiments that may help the classroom teacher familiarize students with the more common fungi:

1. **To study the growth of bread mold,** place a piece of bread in each of two wide-mouthed bottles, such as Mason fruit jars, and leave the jars uncovered for a day in the air of a kitchen or basement. Then screw the lids on tightly after adding a few drops of water to ensure a damp atmosphere. Place one jar into a kettle of boiling water and leave it there for five to ten minutes. Remove it and stand both jars in a warm place for several days.

Which jar is the first to show signs of mold? Why? How long is it before the other jar shows mold? What does this indicate about the effect of heat upon molds? Can you state any reason why canned fruits do not normally become moldy?

Place a slice of stale bread on a dish. Dampen the bread with water and cover both with a transparent container. When a good growth of mold has appeared, remove the cover and examine the colony of plants.

Note the color, size, smell, texture, and general appearance of the colony. With a hand lens, notice the tiny threads (*hypha*) which form a network throughout the bread. Look for vertical stalks with knobs at their tip ends which indicate the presence of spore containers called *sporangia.*

2. **To show the development of different molds in food materials,** expose a variety of foods, such as bread, cheese, citrus fruit skins, banana peels, cold cooked potatoes, or cut carrots to the air. Moisten each item, place it separately in a glass jar or tumbler, and cover each with a lid or Saran Wrap. Place the jars in a warm, dark place. Each day examine for molds.

Check for the variety of molds, their color, size, type of growth, and other distinguishing characteristics. Do different kinds of mold appear on the same or on different substances?

Vary the experiment by exposing the foods to the air in closets, kitchens, or basements. Examine daily to see if there is any variety in the molds collected.

3. **To show the mycelium of a mold,** partially fill test tubes or other transparent containers with liquid nutrients such as fruit juices, cooked potato broth, concentrated soup broths, or watered jellies. With a needle, scrape some spores from the surface of the molds you have cultivated and place them into the liquid medium. Set them in a warm place and make regular observations with a hand lens or magnifier.

Watch for the formation of the *hyphal* threads which later branch and intertwine to form a mass of filaments known as the *mycelium.* Note when the sporangia form and what quantity of mycelium is present when this occurs. How do the parts on the surface differ from those below? Place some mycelium on a slide and examine it with a low power microscope.

4. **To learn some of the conditions favorable to growth of molds.**

   a. *Moisture.* Place a piece of moistened bread and a piece of dry bread side by side on a dish and cover with a transparent cover. After a week, examine both closely. Is there more mold on one piece than the other? Why?

   b. *Temperature.* Prepare three similar cultures of molds. Place one in a very cold place, one in a warm place, and the third where it is quite hot. After a week, bring the three together and compare the results. What occurred? Why?

   c. *Air Supply.* Prepare three similar mold cultures. Wrap one tightly with Saran Wrap (which allows practically no oxygen to pass through it). Place the second in a large covered container which contains a supply of air. The third should be placed where a breeze can pass over it. Watch for structural differences as well as differences in growth rates. Continue this experiment for at least two weeks.

   d. *Light.* Place a mold culture in a dark location and a similar one in a lighted location with the temperatures of both approximately the same. Are there differences? If so, what are they?

5. **To learn of the fungi known as yeasts,** prepare two wide-mouthed jars by placing equal quantities of water in each. Dissolve a small quantity of sugar in each. Now place some powdered yeast, or a yeast cake, in one container and keep the other as a control. Place a rubber glove over the mouth of each container and set in a warm location.

Watch for changes in both liquids and particularly notice any changes in the rubber gloves. Later examine for odors, the effect of any gases formed on lighted candles, and the presence of organisms within the liquids.

If a microscope is available, prepare a slide of the yeast culture. You should be able to observe the actual "budding" of these fungi cells.

6. **To study the spore-bearing structure (fruiting body) of a fungus, the mushroom.** Mushrooms can be collected from yards, woods, or meadows, or the cultivated form can be purchased from a grocery store. The mushroom itself is the above-ground, spore-bearing structure that indicated that a fungus plant with its filamentous threads is living below ground. The hypha gather nourishment by breaking down organic material in the soil and may remain hidden there until the soil is disturbed or the hyphae fuse together to form the well-known mushroom body. Besides learning the basic mushroom parts of cap (pileus), stalk (stipe), and gills, which are under the cap and contain the spores, students may want to slice through a mushroom or make spore prints. The latter are made by selecting a mature mushroom, slicing off its cap, and placing this gill-side down on a piece of white paper. (The spores are of different colors for different types of wild mushrooms and black paper may be more satisfactory for some of the wild mushrooms that may be collected.) The cap should then be covered with a tumbler or other container to keep drafts from blowing away the spores. After several hours (the time length is dependent on the mushroom's maturity), the tumbler and cap are removed carefully from the paper. A print containing literally thousands of microscopic spores remains. Although mushroom spores are notorious for their low percentage of germination, you may want to cut strips from the paper and place these on different types of media, such as potato broth, thin jellies, or soups to see if you can get the spores to grow and start the mushroom mycelium. Pieces can also be taken from the solid stipe or cap, and when placed on proper nutrients, these tissues will form hypha threads.

A variation on these experiments is to gather the bracket or shelf fungi from trees and decaying stumps and make prints of these *pore* fungi.

These are just a few of the activities a classroom teacher may want to try. References for more extensive study and experimentation are listed below to help you and your students learn that fungi, too, can be fascinating.

## References

1. J. David Lockard. "Functional Fungi." *The Science Teacher,* 30:6-10. February 1963.
2. Elizabeth J. Moore and Verne N. Rockcastle. "Fungi." *Cornell Science Leaflet.* March 1963. New York College of Agriculture, Cornell University, Ithaca, N. Y.
3. E. Laurence Palmer. *Fieldbook of Natural History.* McGraw-Hill Book Company, Inc., 330 West 42nd St., New York City. 1949.
4. Verne N. Rockcastle. "Plants Without Flowers." *Cornell Science Leaflet.* December 1961. New York State College of Agriculture, Cornell University, Ithaca, N. Y.
5. Dorothy Sterling. *The Story of Mosses, Ferns, and Mushrooms.* Doubleday and Company, Garden City, N. Y. 1955.
6. Herbert S. Zim. *Plants.* Harcourt, Brace and Company, 383 Madison Ave., New York City. 1947.

# KEYS—

# An Aid to Biological Identification

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Each of you has a key or group of keys in your pocket or purse. These keys open desks, homes, cars, or cabinets. The keys are not interchangeable; the house key will not open the car. Only the car key will do this.

Biological keys are similar to keys on your key chain. Each key unlocks *only* the identity of certain plants or animals. The flower key will not work on algae and the insect key will not help you identify trees.

Keys are important for they help children to observe plants and animals closely and see how they are similar and different from one another. Keys enable student and teacher to identify groups of plants and animals and see some of the organizational patterns used by scientists.

### Developing the Use of a Key

In the lower elementary grades, it is possible to introduce a "key" by using paper of two colors cut as large and small circles and squares (Figure 1). When children are asked to divide the pieces of paper into two equal groups, they usually divide them by color. Children can be shown that the papers have certain similarities and also certain differences. The initial division can be made by color, size, or shape. It should be stressed that *any* of these three divisions would be correct.

A simple key can be made for the eight bits of paper in Figure 1. This key is for black and red squares and circles of large and small size.

In this key, the child need know only six words and seven numbers, a simple task for most first graders. The key is divided into pairs or couplets. The first two are both indicated by the number 1 and the two alternatives are black and red.

1. Black (2)
1. Gray (5)
2. Large (3)
2. Small (4)
3. Square
3. Circle
4. Square
4. Circle
5. Large (6)
5. Small (7)
6. Square
6. Circle
7. Square
7. Circle

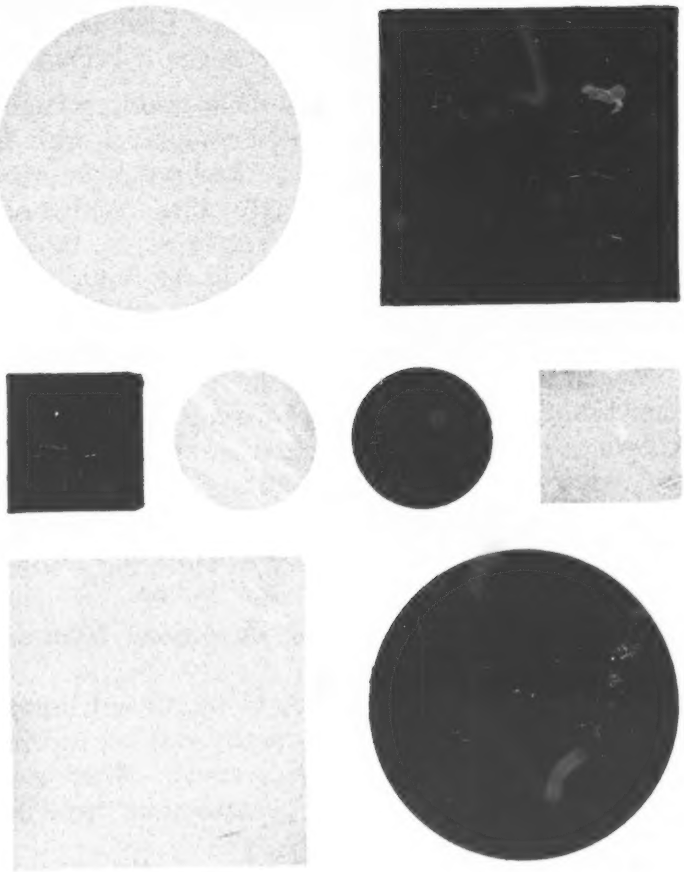


FIGURE 1.

The number *after* the color in parentheses tells you where to go next on your key. The student can now pick up one of the eight pieces of paper and "run the key" to find out where it belongs according to the characteristics; black-red, large-small, or square-circle.

More advanced keys for older classes may be made by using nails and screws of various metals, lengths and types of heads.

The simple key for paper can then be modified for trees, flowers, or animals. Since trees are stationary, easily located, and identified by their leaves by most children and teachers, they provide an excellent source for demonstrating the use of a key to indicate differences and similarities. In any key, the first pair of number 1's usually divide the organisms into nearly equal groups. In the sample key for eight trees, you will note that the first four are evergreens and the other four are broad leaf trees.

Have the children make a collection of all the tree leaf types on the school grounds. From these leaves, develop a key for their identification. (For additional help in tree characteristics, see the bibliography.)

Even in the dead of winter, the tree key can be used with leaf characteristics for evergreens. This illustrates to children that some trees lose leaves all at once and others lose them gradually over the entire year. Do not lose the chance to go out on a "winter field trip" *after* many leaves have fallen to show children other characteristics such as leaf scars, types of pith, type of bark, bundle scars, bud number, and a host of other characteristics rarely observed by children as they pass under a tree every day on the way to or from school.

### Insect Key

In the late spring or early fall, it is possible to set up keys for common insects with a minimum of terminology for the upper-elementary grades. You will note that the following key is arranged a bit differently than the tree key. In this key, the two parts of a couplet are indicated by letters rather than numbers and the two parts of the couplet are separated. As in the tree key, the letter in parentheses indicates the next letter that you go to. The two parts of the couplet give you a definite decision to make. For A, it is to determine wings or lack of wings on the insect.

The annotated list of keys and charts given at the end of the article will help in the identification of some plants and animals. The list is not complete, but gives a few of the elementary, intermediate, and advanced keys available. The advanced keys listed are difficult and most teachers will have a hard time with them unless they have taken advanced courses in the field.

Through the knowledge of the use of keys, children will learn how to make careful observations, logical decisions, and see the differences and similarities of living things.

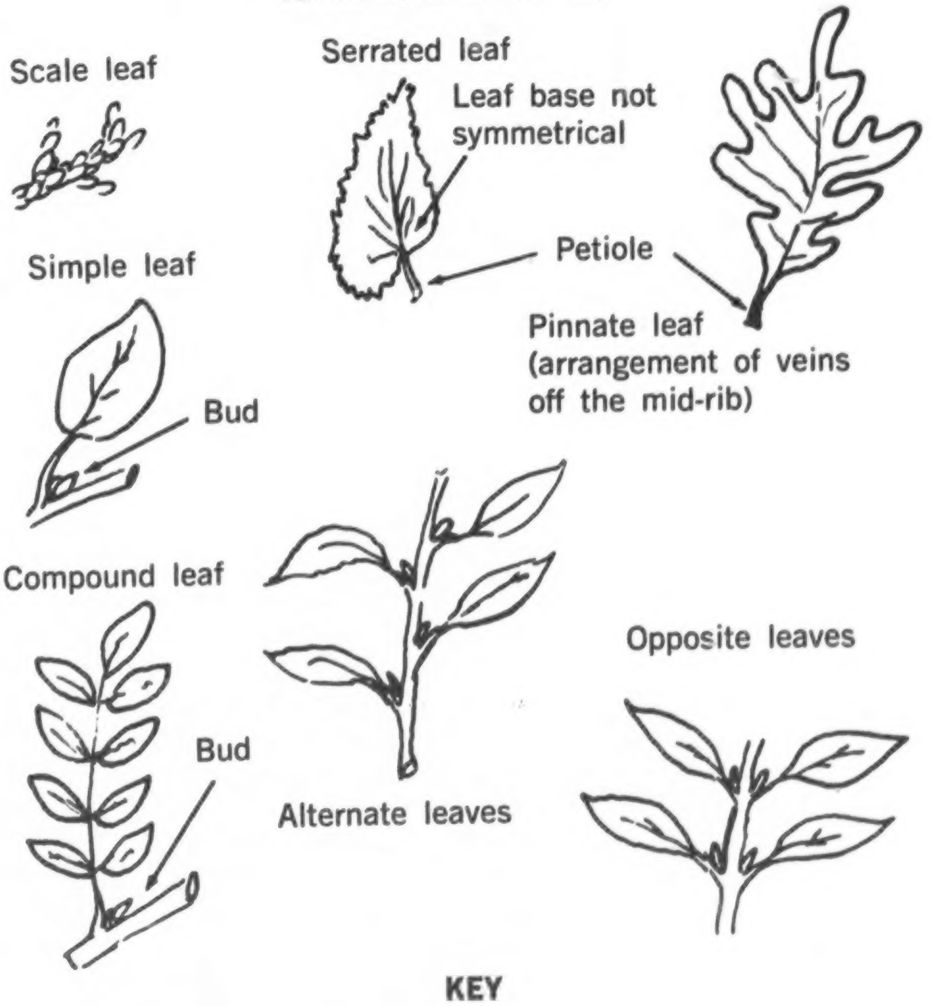
### Elementary Keys or Charts

Audubon Nature Charts, *Twigs, Simple Leaves, Compound Leaves, Evergreens.* 25¢. National Audubon Society, 1130

## A SIMPLE KEY FOR EIGHT TREES

This key can be used for Oak, Maple, Elm, Ash, Cedar, Pine, Hemlock and Spruce trees. (You can modify this key for the trees around your school.)

**Terms used in the key:**



### KEY

1. Evergreen trees, leaves scale-like or needle-like (2)
1. Broad leaves, lost in fall of the year (5)

2. Leaves needle-like, 2-5 needles in a bundle .......... **PINE**
2. Leaves not in bundles (3)

3. Leaves scale-like .......... **CEDAR**
3. Leaves not scale-like (4)

4. Short, stiff leaf, 4 sided leaf, found on all sides of the twig .......... **SPRUCE**
4. Short leaves, flat and blunt at the free end .......... **HEMLOCK**

5. Simple leaf (6)
5. Compound leaf .......... **ASH**

6. Leaves arranged opposite on the twig .......... **MAPLE**
6. Leaves arranged alternately on twig (7)

7. Leaf pinnate and deeply notched or lobed .......... **OAK**
7. Leaf not lobed, serrated (jagged) edge, leaf base near petiole not symmetrical .......... **ELM**

Fifth Ave., New York City. (Help with identification of trees, also good for bulletin boards.)

Watts, May T. *Tree Finder,* (Leaf characteristics). 25¢. Nature Study Guide, Naperville, Ill. (Very good key for elementary grades or for person with *no* experience with keys.)

Zim, Herbert S. and A. C. Martin. *Trees,* (Leaf characteristics). $1. Golden Nature Guide, Golden Press, New York City. (This is not a key in the true sense, except on page 5, but trees may be located easily. Series also contains books on Birds, Flowers, and Insects which are good.)

**Intermediate Keys:**

Harlow, William M. *Fruit Key and Twig Key to Trees and Shrubs of New England.* $1.25. Dover Publications, Inc., New York City. (Very helpful in winter for identification, photographs very good.)

Jacques, H. E. *How to Know the Insects.* Spiral binding $2. William C. Brown Company, 135 South Locust, Dubuque, Iowa. (Very good key of intermediate difficulty, well illustrated, information on catching and collecting as well as mounting insects. Other books in the "How to Know" series: *Trees, Plant Families, Spring Flowers, Beetles, Grasses, Mosses,* and others. Price between $2 and $4.25.)

Watts, May T. *Flower Finder* (Spring Wildflowers). 50¢. Nature Study Guild, Publishers, Naperville, Ill.

Watts, May T. *Master Tree Finder* (Leaf characteristics). 50¢. Nature Study Guild, Publishers, Naperville, Ill. (Similar to simplified version but amplified.)

**Advanced Keys:** (Master the use of simple and intermediate keys before you attempt one of these. Use these in college or town libraries as they may be very expensive. All are excellent in their field.)

Edmondson, W. T., Editor, *Fresh-Water Biology,* Second Edition (Ward and Whipple). John Wiley and Sons, Inc., New York City.

Fernald, M. L., Editor. *Gray's Manual of Botany,* Second Edition. American Book Company, New York City. (Ferns and Flowering plants of Northeast United States and Canada.)

Metcalf, Z. P. and C. L. *Key to the Principal Orders and Families of Insects,* Third Edition. $1.50. Mrs. Metcalf, Riverside, Calif.

Pennak, Robert W. *Fresh-Water Invertebrates of the United States.* Ronald Press Company, New York City.

## A KEY TO EIGHT COMMON ORDERS OF ADULT INSECTS

This Key can be used for Isoptera, Hymenoptera, Diptera, Orthoptera, Odonata, Coleoptera, Hemiptera, and Lepidoptera insects.

**Insect characteristics:** Three pairs of jointed legs, three main body parts, no wings, or one pair, or two pairs of wings.

A. Insects without wings or one pair of wings (B)

B. Insects with one wing pair (other pair is vestigial) —DIPTERA (flies, mosquitoes)

B. Ants or ant-like insects with no wings except during mating season (C)

C. White insects (grey with two wing pairs when mating) live in wood, thorax and abdomen are not wasp-waisted as in ants. —ISOPTERA (termites)

C. Red or black insects, abdomen-thorax connection VERY restricted, wings during mating season. —HYMENOPTERA (ants)

A. Insects with two pairs of wings (D)

D. Insects with "powder" (scales) on wings. —LEPIDOPTERA (moth, butterfly)

D. Wings not covered with "powder" (scales) (E)

E. Both wing pairs entirely membrane-like (F)

F. Large insects with long thin abdomen. —ODONATA (dragonfly)

F. Small to large insects with restricted ("wasp waist") thorax to abdomen connection. —HYMENOPTERA (bee, wasp, hornet)

E. Outer wings not membrane-like or only outer part is membrane-like (G)

G. Insects with outer wings as hard covers. —COLEOPTERA (beetle)

G. Insects without hard outer wing as cover (H)

H. Outer wings thickened near base, remainder membrane-like, mouthparts for sucking, wings fold on back across each other. —HEMIPTERA (stink bug)

H. Outer wings leathery, mouth parts for chewing, wings not folded across back. —ORTHOPTERA (grasshopper, cricket, cockroach)

3 neg

# Kindergarten Rock Study

**DOROTHY MASON**

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KINDERGARTEN children can begin organized science study if the activities are appropriate to their learning level. A science concept is developed most successfully for young children through a series of experiences which progress from simple observation to observation of a specific "scientific-process" orientation where children make a guess, test, and conclusion—naturally, at a very informal elementary level. Each experience should build upon the last for those children mature enough to organize and retain ideas. However, for children whose attention spans are short and unreliable, each experience should also be its own reward.

For example, the concept that "rocks around us are different in many ways" can help young children gain science skills and knowledge applicable outside the classroom. In kindergarten, children can learn about rocks through a sequence of experiences such as the following:

1. One day on the playground a child brought me a stone and I commented, "Oh, what a pretty stone." Soon other children were bringing me "pretty stones."

2. A child who lives on the waterfront then brought "pretty stones from the water" to school. They were put on display in an egg carton on the science table. In the discussion which followed, I elicited the suggestion that "we put the stones back in the water to see how they looked when Michele found them."

3. Further discussion initiated the project of bringing rocks from the children's homes. The resultant display obviously showed how different looking rocks are found at different homes (places) which represented a kindergarten level concept of the origin of rocks. (Kindergarten children need to develop a concept of space near and about them before they can comprehend a concept of "far away.")

4. In picking up stones on the playground the pupils discovered that "pretty stones can be different colors." Each day they found different-colored stones which were collected for the science table. Then again through channeled discussions, the pupils decided to sort the different-colored stones. Papers of various colors were pasted in the bottom of each section of an egg carton. The children took turns sitting at the science table matching rocks from the collection to the various colors.

5. One day, I brought a piece of pegmatite which has large pieces of shiny biotite mica in it. The children were very pleased with the "shiny parts" of the stones and I suggested that they look for other stones that sparkle. A few were brought in each day, and out of this project developed another one: "What do you see in stones?" Fossils, granite, gneiss, striped sedimentary stones, and many other kinds of

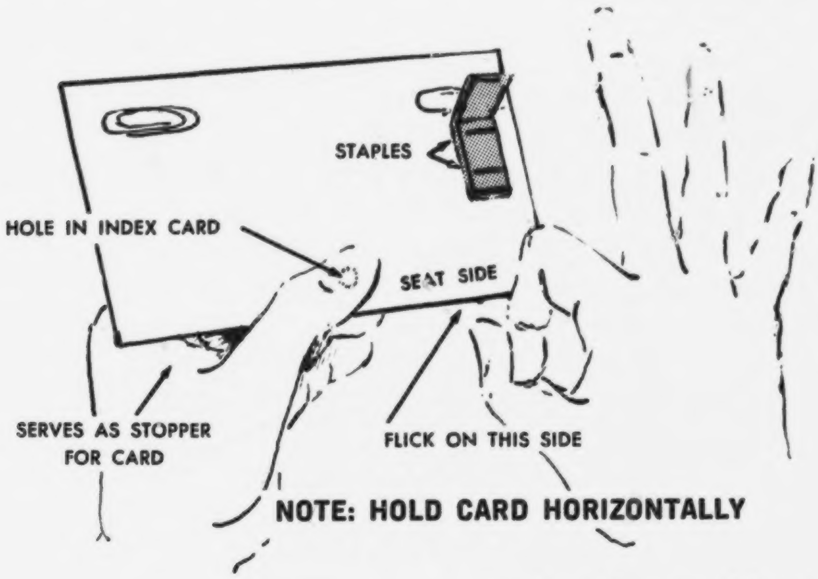
pitted, spotted, banded, and porous rocks were collected.

6. One day a child picked up a rock on the playground and rubbed it on the concrete sidewalk. It made a mark and he said excitedly, "Look, this stone writes!" He tried other rocks for the same result, keeping those that "wrote" and discarding those that did not. His enthusiasm, which I supported with many comments of praise and approval, was contagious and soon many children were trying rocks on the concrete. Some rocks made darker or different colored writing; some rocks (softer) worked better than others for writing. We used another egg carton to collect rocks that could write in one half and in the other half—rocks that could not write. The "writing rocks" were labelled with a crayon.

7. Another day I showed the children a piece of coquina. They observed that it looked like shells from the beach. I replied, "Yes, it does look like tiny shells, and do you know that this rock can make bubbles?" Kindergarten children adore bubbles; they "bubble" their milk through straws and blow soap bubbles, and they were greatly intrigued with the idea of rocks making bubbles. I showed them a bottle of vinegar, poured some in a thick glass container, added the coquina—result: bubbles! The children immediately wanted to try other kinds of rocks. This was a highly-motivating and dramatic experience in testing and classifying. We placed the vinegar bottle, testing jar, a collection of miscellaneous rocks, and an egg carton on the science table. One half of the carton was given a label with bubbles drawn on it; the other side was given a blank label (no bubbles) and the children took turns testing and sorting. Several of the children were soon able to pick out rocks they thought would be most apt to make bubbles. This entire process of testing for lime content (unnamed as such to the children) was a first experience in the scientific process: collection of materials or data (rocks), formulating an hypothesis ("Maybe other stones will make bubbles"), testing (in vinegar jar), and forming a conclusion (sorting rocks into those that will or will not make bubbles).

As a conclusion and a solution as to what to do with all the rocks we had collected, each child was given an empty cigar box to decorate and then allowed to choose ten (counting experience) rocks that he could put in the box to take home. This further established the organized collecting of rocks.

In their study of rocks the children had experiences in color and texture discrimination, classification, simple technical vocabulary, and the scientific process. Further evidence of learning and its change of behavior as a result of this study of rocks may be cited by noting that on the day the rock collections went home, 30 kindergarten children went home carrying 300 rocks among them and not one rock was dropped, thrown, or lost en route!



NOTE: HOLD CARD HORIZONTALLY

# Was Galileo Right?

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Most children snicker in disbelief when told that a ball thrown horizontally, over level ground, will reach the ground simultaneously with one dropped at the same time and from the same height as the one thrown. It is easy to see why children feel this way, you may have your doubts also!

A problem arises when we try to release the two objects at exactly the same time. Our reflexes are not sharp enough to provide the degree of accuracy desired in the classroom. Because of this limitation, many teachers fail to illustrate this principle and only discuss it.

The device illustrated here will prove useful in demonstrating this phenomenon. All that you will need is a 3 x 5-inch card with a hole punched on one side (a library index card works well), stapler, small piece of cardboard or oaktag, scissors, and two paper clips.

To operate the device, hold the card horizontally with the thumb and third finger of one hand, position the paper clips as illustrated, and "flick" the "seat" side sharply with a finger of the other hand.

The clip in front of the oaktag will be pushed forward and pulled down (downward pull by gravity). The other clip will be pulled straight down. Listen to the sound the clips make as they hit the floor. After a few practice "launches," you will find that the device helps to prove that Galileo was right.

# School Ground Conservation

**SALLY DeROO**

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Plymouth Public Schools
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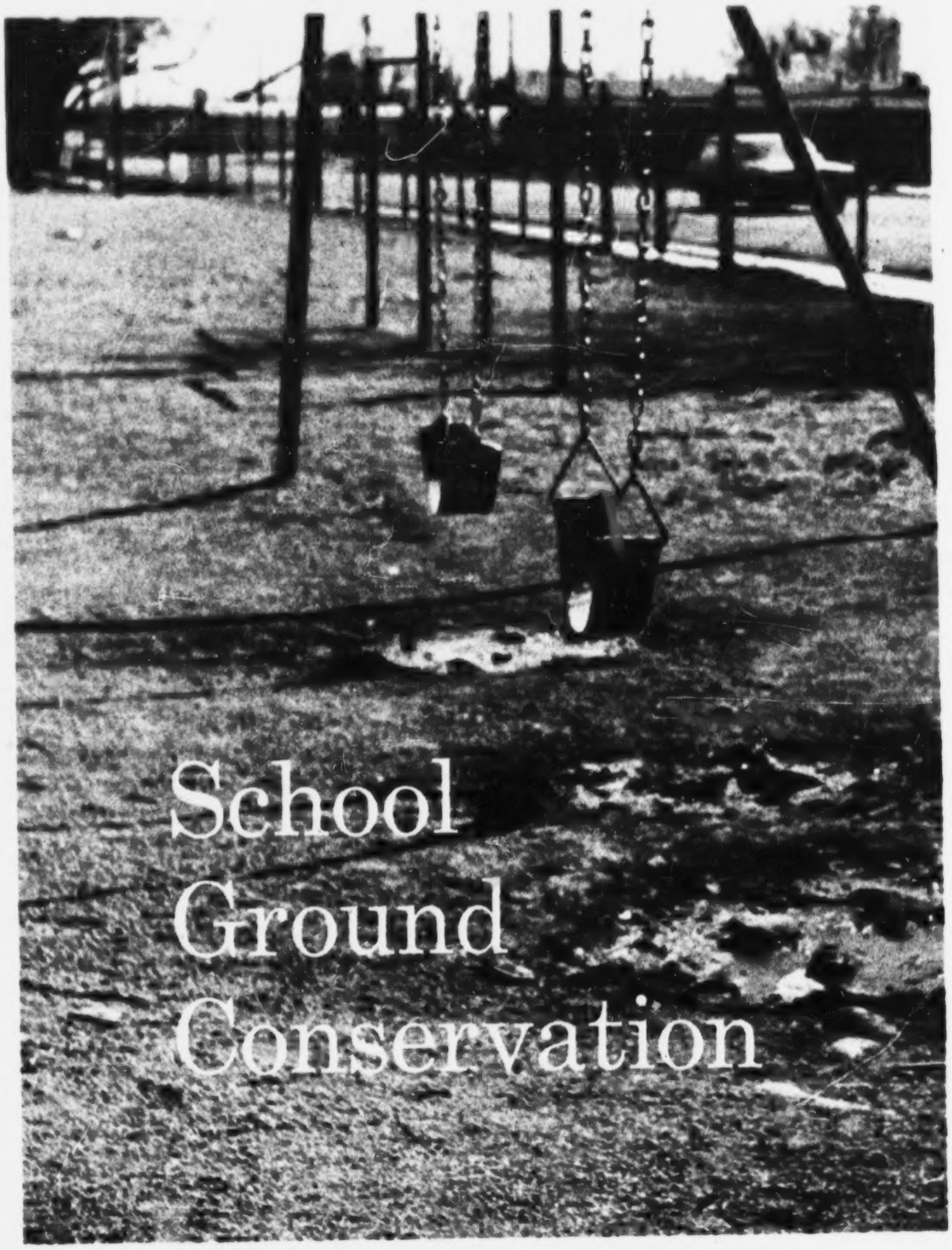


At school, a barren playground is often the rule, not the exception. A worn tree and possibly several clumps of weeds border the grounds. Mud puddles in April and dust storms in May create a dismal view as a single sparrow searches for a weed seed. This was once the spot where grass, trees, and animals enjoyed their freedom. Now the children play on this lifeless ground. Unfortunately many of our school grounds show such poor examples of conservation. To eliminate the problem of bare ground, many schools have black topped the area around their buildings, thus, covering all signs of the living environment.

### Children Will Help

You need not be a science major nor an expert on conservation to help improve conservation practices around your school. Children love to help care for their school grounds. On this point I speak from experience. I once taught at a school where all the children rode buses daily. When the buses lined up in front of the school to bring and gather the children, every shrub and blade of grass felt the scramble of youngsters' feet. The grounds were a mess when it rained and a dust bowl when the mud dried. We worked out a plan of ground care. Each grade took part in improving the appearance of the school. The lawn that the sixth grade planted stayed green a long time. It was rewarding to see a youngster stop and walk a corner square instead of rounding it off.

Children must be taught to care for what is their heritage. Through conservation programs in our schools, these basic practices will be instilled in their daily lives.

Why not begin with a small area which is badly in need of improvement around your school? All areas around a school building can stand a little care, especially in the spring. A general clean-up operation is an excellent beginning. Conservation is providing lands for enjoyment and esthetic values as well as preserving and maintaining them for the future. Piece by piece, an effective program involving all the children can be fit together with real results.

The first step is to decide where to begin. That little area outside your window could so easily be green and colorful; it may be the spot. Wherever you begin, choose a place which will take a relatively short time to develop with dramatic results.

Often, grass borders along the school walks show no trace of grass or have a bare path cutting across them. (Check with the custodian before you begin. He can offer excellent suggestions and aid.) Casually point out to your group how the area looks. Observe the hollow spot where valuable top soil has been blown or washed away. On a rainy day, point out the soil being carried away from the areas where protecting grass cover has been stripped away. Small mudflows and hundreds of rivulets carrying soil can be seen. (Rivers like the Mississippi and the Nile carry tons of soil during floods.) Notice the direction of these water and mudflows and mark the location of miniature deltas for future observation. Compare these areas of the playground with a plant-covered area.

Ask the children for suggestions for improving or correcting problem areas. In the early grades, suggestions may be recorded and later included in the reading program as experience charts. Letters may be written to the local conservation officer for help. The local lawn services may be consulted for assistance. A meeting with the custodian may be arranged so he can discuss his duties and problems he must overcome in maintaining the school grounds. He may also show the equipment necessary for lawn care.

Other areas where erosion has taken place on a large scale around the school and neighborhood may be recorded such as; in new housing developments, along freeways, or other large construction areas. A map of such areas in the school district may be made by the children. If your school is fenced in, examples of rill and gully erosion in miniature can be seen around the base of unprotected fence posts. Black-topped playgrounds are not a complete loss to prove erosion takes place. Mark off an area about ten feet square and sweep it clean. You will be surprised how much soil has been blown and washed in from places unknown.

There are several simple experiments to show how plant cover protects the land. Each is easily done in the classroom. The following is one example.

### How Plant Cover Protects Soil

*Materials:*

2 cookie sheets
2 cake pans, square type
Soil
Sprinkling can
Two bricks
Sponge
Water
Newspaper

*Directions:*

1. Select the work area and cover it with paper.
2. Fill two cake pans with soil.
3. Wet the soil in one pan and sprinkle grass seed on the surface.
4. Cover the seed with a thin layer of soil, no more than ⅛ inch.
5. Water the pan containing the seed again. Do not water too often; too much water will cause the seed to rot.
6. Place the pans aside and wait for the seed to germinate and grow.
7. When the grass is about an inch tall, set up both pans using the bricks and cookie sheets. See Figure 1.
8. Sprinkle equal amounts of water over each pan, representing rain.

*Results:*

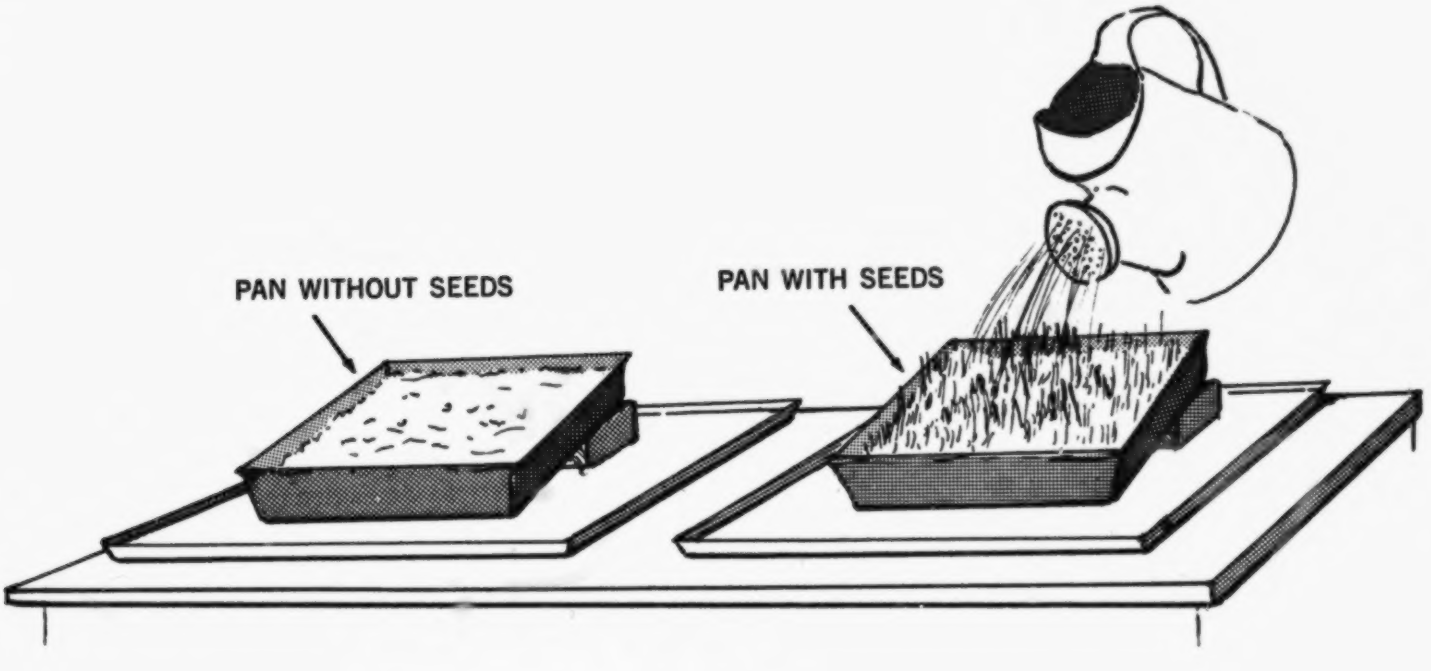
The children will see the importance of plant cover. The soil with cover has:

1. Less water in the cookie sheet;
2. Cleaner water as it drains;
3. More water absorbed by the grass;
4. Less soil, if any, washed away.

For truly dramatic results, set the experiment outside on a rainy day. This is an excellent time to point out what damage raindrops can do to unprotected soil. Notice how the drops push at the soil and work it loose. This same erosive process can be observed on sandy areas of the playground. After a heavy rain, the holes made by the pressure of the raindrops can be seen.

The play area will offer countless experiences in practicing conservation of plants and soil. A crowded area will seem less congested with a shady tree, planted as a class project, in each corner. The screaming of youngsters will be quieted as a bird begins a nest in last year's tree. That steel fencing will seem less confining as vines of ivy add shade and color. If watered and planted in loose soil, grass seed will grow almost anywhere.

Why not brighten up that school yard and practice a little plant conservation this spring?



**WALTER BEHM**
Principal
S. S. Stewart Community School
Flint, Michigan

# Cold Weather Science

During the winter months, the changes in nature can provide many opportunities for students to do interesting and enlightening studies outdoors. Listed in this article are a few of the many cold weather field activities which can be handled successfully by almost any elementary class. Such experiences can help a child to increase understanding of his own environment. Of course, the way these ideas are used will depend upon the teacher's interest and ability and the needs and interest of the class.

### Icicles

During the winter, icicles can be observed hanging from roofs and eaves or under a leaky outdoor faucet. This familiar cold weather phenomenon can be the source of several questions and investigations. Who can find the longest icicle? Where was it found? What conditions made it? What was the air temperature? At what rate does an icicle melt? At what air temperature does it melt? Weigh an icicle. What is its weight? Does it weigh as much when it is a liquid?

Another product of the cold seasons is ice. If there is a pond or lake nearby, have the students measure the thickness of the ice at the edge of the pond. How much does the ice increase or decrease in thickness in a week? What has the daily temperature been? What is the temperature of the water beneath the ice?

### Snowman

Why not have the students make a scientific study of a snowman? After a snowfall, when the conditions are appropriate, the class can build a snowman in the school area. Then, by observing and recording data, the students can study the changes in the snowman as it melts. How tall is the snowman? On what kind of days does it melt? How fast (inches) does it melt each day? What is the daily temperature? Does it melt at all when the temperature is below 32°? Does it melt on one side more than another? How does the melting side relate to the position of the sun? Does it melt more at the top or bottom? Why?

### Snow on Roofs

Encourage children to observe and study snow on roofs of houses and other buildings. Which houses have snow on their roofs? Does the angle of the roof play a part in this? Do both sides of the roof have the same amount of snow on them? What bearing does the direction the house faces have on this? Does the snow melt at the same rate on all houses? How do you explain the fact that snow first melts in only certain areas of the roof? What about insulation?

### Purity of Snow

Children often eat snow while playing outside. To study its purity, collect a quart of freshly fallen snow and allow it to melt. It can then be poured into another container through filter paper. How much did the quart of snow weigh? How much water did it make? Was there dirt on the filter paper? Collect snow periodically from different areas to check it for cleanness. Is snow pure because it is clean?

### Salt on Snow

The practice of putting salt on ice and snow offers an interesting exercise for the class. Sprinkle salt on the surfaces of snow-covered cement, brick, and wood. The amounts and kinds of salt should be equal, and the surfaces treated should be of the same dimensions. On which surface does the ice or snow melt first? How long does it take? What is the temperature? Is the sun shining? Does the ice melt where it is not treated with salt? Would snow melt as fast in the shade? What effect does the salt have on the surface of the materials? Is salt better to use than sand?

These suggested activities are only a few of the many interesting investigations that can be conducted outside during the winter months. Not only will cold weather activities stimulate thinking and curiosity, certain basic tools of science can be utilized. For example, measurements must be taken to supply material for graphs, reports, or summaries. In addition, these outdoor science studies offer fresh air, exercise, and good fellowship for student and teacher alike.

# OCEAN CURRENTS

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*Oceanography* is the study of the oceans, and in recent years, particularly during the International Geophysical Year (IGY), a number of fascinating and important discoveries have been made concerning these great bodies of water. For example, it has been found that underneath many of the great surface currents in the ocean, such as the Gulf Stream, there are other currents that flow in the opposite direction. Along the equator in the Pacific there is a gigantic underwater current many times larger than the Mississippi River, the Cromwell Current, that flows from west to east in opposite direction to the east-west current that carried Thor Heyerdahl and Kon-Tiki from South America to the South Sea Islands. Spherical nodules rich in manganese, cobalt, and copper have been discovered on the ocean bottoms. They may eventually be mined to augment our diminishing supply of critical minerals.

Fortunately, some of the important phenomena of the oceans can be studied in our classrooms using material and equipment available everywhere. Also, the study of these phenomena is an excellent way to gain understanding of some very basic scientific principles.

In most of the oceans there are vast flowing currents that are of great importance to the people that live along the shores that are affected by these currents. The best known current is the Gulf Stream which is a stream 20-30 miles wide flowing out of the Gulf of Mexico along the coast of the Southeastern United States and across the North Atlantic to warm the shores of the British Isles and Northern Europe. The Gulf Stream is believed to be caused by the intense heating of the ocean waters in the tropical Gulf. *As water is heated it expands and becomes lighter and is replaced by colder, heavier water.* Cold water from the north forces the warm water upward and northward in the Gulf Stream.

## Classroom Demonstration

Using two milk bottles, a 3 x 5 card, some warm and cold water, and a little food coloring it can be shown that warm water is replaced by cold water. Fill one milk bottle with warm water and the other with cold water. Mix a little food coloring into the warm water. (Wait about a minute or so for the food coloring to disperse throughout the water.) Place the 3 x 5 card on top of the milk bottle containing the cold water. Turn the bottle upside down and place it on top of the bottle containing the colored warm water. (The upward force of the outside air will hold the card over the opening of the bottle when it is tipped over.) Remove the card. Observe carefully the area where the two bodies of water make contact. (Figure 1.) Are these currents flowing in both directions? In which direction does the colored warm water flow? Why? To see whether or not warm water would replace cold wa-

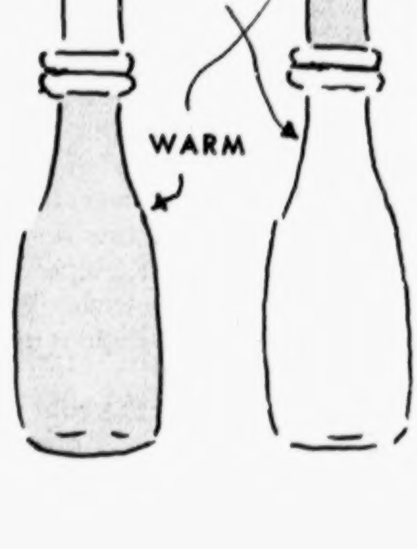


FIGURE 1. FIGURE 2.

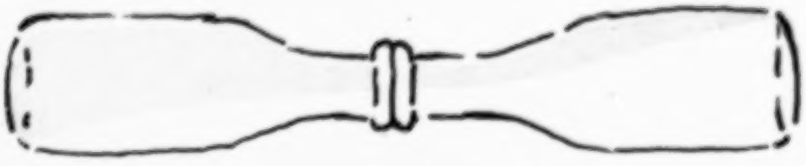


FIGURE 3.

ter, reverse the bottles and place the warm on top and the cold on the bottom. (See Figure 2.)

**Reverse Current Demonstration**

For an even more realistic demonstration, try placing the two milk bottles on their sides, as shown in Figure 3. The two milk bottles of water can be placed on their sides by first placing the bottle of warm water on top of the cold water as illustrated in Figure 2. Now pick up both bottles, with one hand near the end of each bottle, press the ends inward slightly as you move the bottles and set them on their sides. Keep your hands on the ends of the bottles. (It might be advisable to practice this demonstration in a sink.) With the bottles on their sides, we can see the warm colored water move up and over the cold water. The cold water flows in a reverse current underneath. Many scientists believe that there is a reverse current underneath most of the currents of the surface of the ocean.

The Mediterranean is an almost landlocked sea that receives a great deal of energy from the sun. Therefore, there is a great deal of evaporation leaving much salt in the water. *Relatively heavy water such as salt water will replace lighter water.* This heavy salt water flows outward along the bottom of the Straits of Gibraltar into the Atlantic. This current is so strong that at times instruments dropped down to measure it have been dashed to pieces.

The flow of salt water can be studied by placing colored salt water (which you can make by adding salt and food coloring to one bottle) over a milk bottle filled with clear fresh water (Figure 4). How does the rate of flow of salt water compare with that of warm water? Try placing the colored salt water in the bottom (Figure 5) and see what happens.

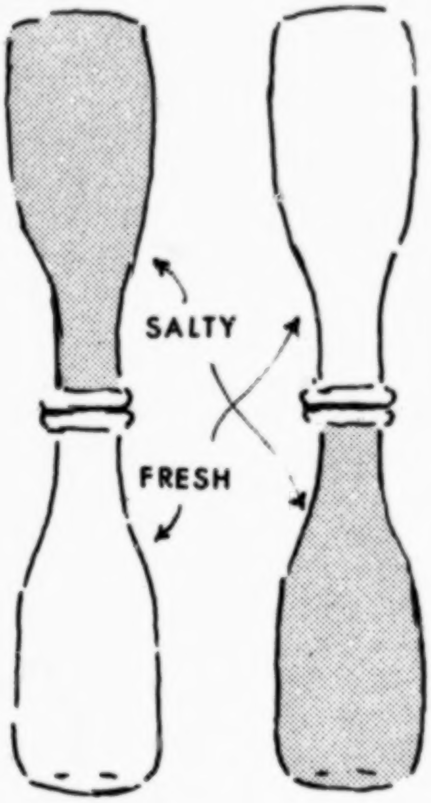


FIGURE 4. FIGURE 5.

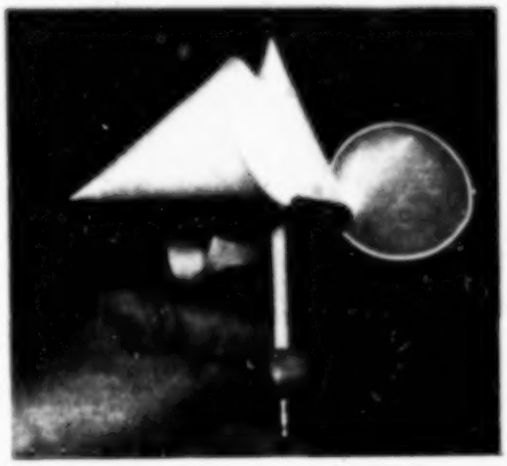
The cold ocean currents from the Arctic and Antarctic nourish a tremendous number of living things. The cold Labrador Current gives rise to the great fishing "banks" off the coast of North America. The Humboldt Current that carries cold water from the Antarctic Ocean along the west coast of South America is perhaps the richest source of life in the oceans.

*More of a gas can be dissolved in cold water than in warm.*

The food for both plants and animals in the oceans is manufactured through photosynthesis by green plants, primarily algae. Carbon dioxide gas is one of the essential ingredients for photosynthesis. Of course, all living things need oxygen. To be available to plants and animals in the oceans, both of these—carbon dioxide and oxygen—must be dissolved in the water. The cold ocean currents contain a great deal of these dissolved gases.

Fill a Pyrex jar with water from the hot water tap and another Pyrex jar with an equal amount of water from the cold water tap. Blow an equal number of puffs of air through a drinking straw or piece of glass tubing into each container of water. Warm both containers on a hot plate and watch the bubbles of air form. These bubbles are formed from air that has been dissolved in the water. In which water was there the greater number of bubbles formed?

The United States and several other nations are planning to devote more resources and energy to the systematic study of the oceans. As a result, we will undoubtedly gain a better understanding of this important area of the earth's surface. In the future, our children will study the oceans in much the same way as children today study the air, soil, and rocks.



**ROBERT W. SMITH**
Elementary Science Coordinator
U. F. S. District Number 15
Cedarhurst, New York

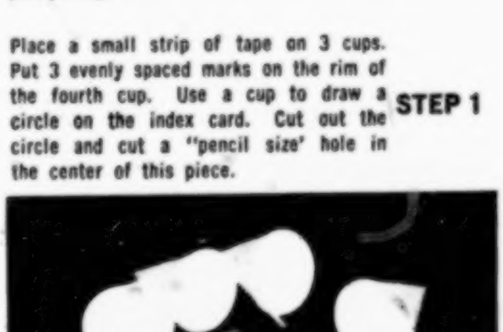
# Anemometer

### MATERIALS

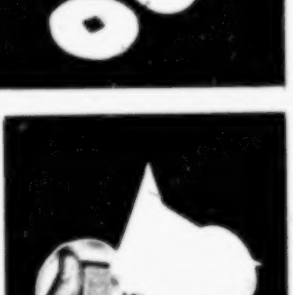
Four small cone-shaped cups, transparent or masking tape, stapler, one index card, and one new pencil (sharpened).

Place a small strip of tape on 3 cups. Put 3 evenly spaced marks on the rim of the fourth cup. Use a cup to draw a circle on the index card. Cut out the circle and cut a "pencil size" hole in the center of this piece.

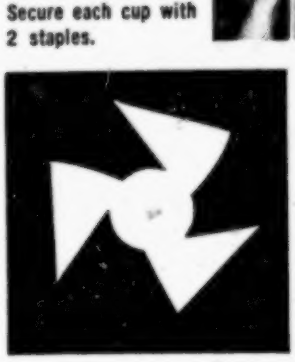
**STEP 1**



**STEP 2**



Tape the 3 cups to the marked spots on the fourth cup. (Be sure that they all face the same way.) Secure each cup with 2 staples.



**STEP 3**

Fasten the "circle" to the opening of the fourth cup with tape. Place the completed structure on the sharpened pencil as shown above.

In a study of weather, teachers are often asked to construct weather instruments. Many of these instruments require many hard-to-get materials and a great deal of time for construction. Here is an anemometer that is simple to make and works very well. It requires a minimum of time and materials, functions well in a slight breeze, and will increase the student understanding of weather instruments.

### Activities

The device can be calibrated in many ways, and should be if it is to be used in the upper grades. First, paint or color one of the cups red or some other contrasting color. This will make it easier to count the number of complete revolutions made in an interval of time. A stop watch, or wrist watch with a second-hand, will also be required in order to calibrate the anemometer. Anyone of the following procedures can be used:

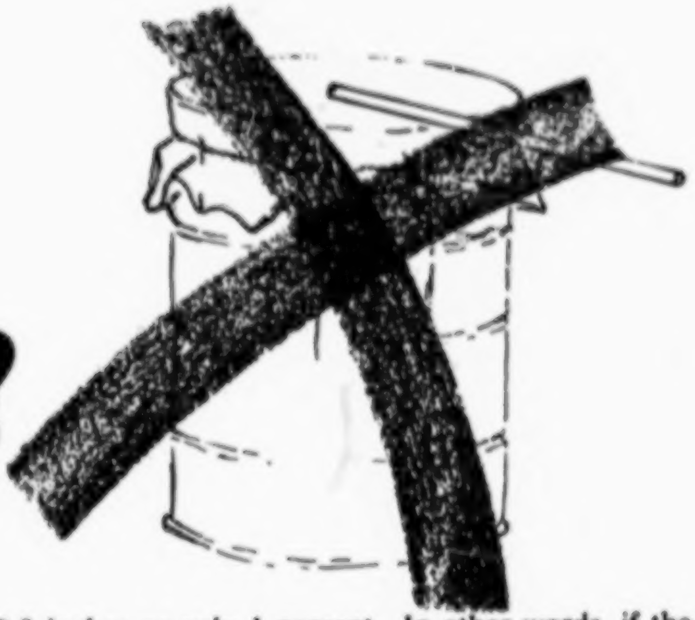
1. A child can ask his parent to take him out in the car on a calm (windless) day. With the car traveling at 10 miles per hour (mph) and the instrument stuck out the window from the start, the child can count the number of turns in 15 seconds. Another child will have to be the time-keeper. Repeat at 20 mph and 30 mph. A chart could be drawn based on these findings. (The wind speed chart will only apply to the particular anemometer being tested, because the size and weight of the cups varies, as well as friction.) The number of turns for a 15 mph wind can be figured by averaging the number of turns for 10 and 20 mph.

2. Using the speedometer on his bicycle, a student can calibrate the device at slower speeds. Needless to say, he will need someone to keep time. (This calibration should be done on a playground and not on a street.)

3. A class trip could be arranged to a high school science department that has an accurate anemometer. The high school anemometer can be used as a standard. Readings can be taken on different days when the wind is gentle, moderate, and etc. The students can count the number of turns their instruments make, when placed as near as possible to the standard, during 15 seconds and check the reading on the standard.

4. The children can calibrate the anemometer on a "still day" by counting the number of turns made in 15 seconds as they walked with it at a normal pace. Call this 3 mph. Running at a moderate speed, call this 6 mph. They could further calibrate this device by figuring that twice as many turns as they counted at 6 mph would indicate 12 mph. This method will not be very accurate, but it can be satisfactory for this type of anemometer, and will show students the importance of having a standard.

# Tin Can Barometer?



**HY RUCHLIS**

General Manager
Science Materials Center, Inc.
New York City

A favorite demonstration illustrating the principle of the aneroid barometer involves covering the top of an empty tin can or jar with a rubber sheet, attaching a straw or light stick to the rubber to serve as an indicator, and then observing "changes in air pressure" as the marker goes up or down.

Unfortunately, this experiment is often not valid and generally does not indicate air pressure correctly. Expansion and contraction due to temperature changes usually cause greater changes in position of the marker than the barometric effect.

Consider the effects of temperature and pressure change on the volume of air in a covered can. On warm or mild days in the late spring, summer, and early fall the temperature generally increases about 20°F from early morning to afternoon. Expansion of gases occurs in proportion to absolute temperature (temperature above absolute zero, or temperature above −459°F). If the morning temperature is 70°F, or 70 + 459 above absolute zero (529° above absolute zero), then a temperature increase of 20°F causes an expansion of volume to $\frac{20 + 529}{529}$, or $\frac{549}{529}$ or 1.04 times the former volume. This represents an increase of 4 percent in the volume of the air in the can.

Even if the temperature rise from morning to afternoon is 10°F instead of 20°F, this still produces a 2 percent increase in volume of air in the can.

In contrast, a barometer change of 0.3 inches from morning to afternoon is fairly large and relatively infrequent. An increase in pressure of this amount causes the fixed amount of the air in the can to decrease $\frac{0.3}{30}$ inches or only 1 percent. In other words, if the tin can barometer is set up in the morning and the center of the rubber is observed to rise by afternoon, this is in all likelihood due to an increase in temperature, and not to a decrease in pressure.

### Rare Event

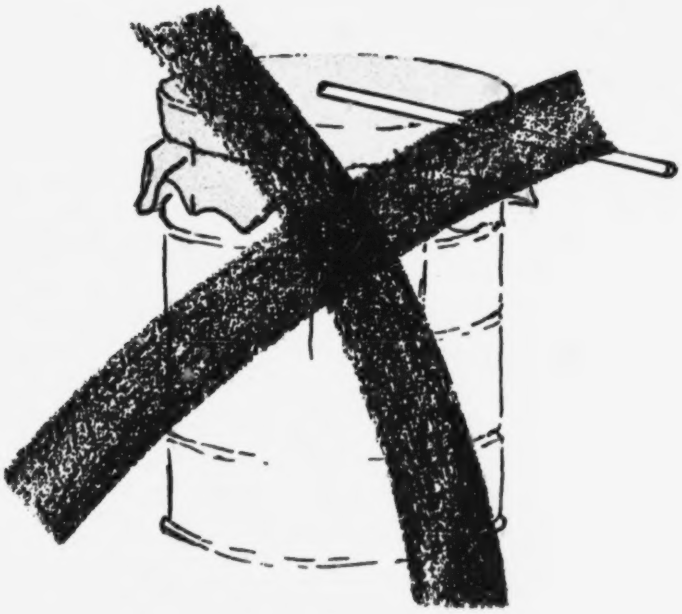
It would be a rare day when an apparent decrease of pressure from morning to afternoon (as indicated by an upward bulging of the rubber) would be due to a pressure change. It would require a pressure increase of almost an inch from morning to afternoon to counteract the effect of the average warm day increase in temperature. Not only is this an extreme change, and quite infrequent, but the indicator on the tin can barometer would then not move much and the incorrect conclusion drawn from the observation would be that no pressure change at all had occurred.

During the winter time, with heated rooms kept at approximately constant temperature, it might be possible to draw some conclusions. But then that also requires that the seal around the rim be good enough to prevent leakage of air in and out of the can for hours.

It is because of this temperature effect that air is removed from corrugated metal containers of aneroid barometers. With air in the container, the interfering effect of temperature change would make the device useless unless corrected.

If the "tin can barometer" is to be used at all, it should be used cautiously. If the effect of pressure is to be demonstrated, the teacher should point out that temperature does affect the volume of air. Then comparisons of position of the points should be made only if the temperature is the same. This could be done on a winter day when the building is heated, or perhaps on successive days at times when the temperatures are equal.

# Tin Can Barometer *Revisited*



**KENNETH W. JOHNS**

Science Teacher
Townsend Junior High School
Tucson, Arizona

The exposé of the tin can barometer by Hy Ruchlis in his article appearing in the March 1965 issue of *Science and Children* was probably something of a disappointment to the many elementary and junior high school teachers who have used the device to show changing air pressure. Nonetheless, we must appreciate this debunking of this apparatus.

Rather than scrap the tin can barometer entirely, let us use it to serve the interests of science instruction. Why not let each student make a barometer of his own?

Have all the students calibrate their barometers at the same time using the same zero point. To insure uniformity, you can supply a dittoed scale. An anaeroid or mercury barometer will serve as a control. Let the children place their barometers at different places in the room—some in sunlight, some in shade. Suggest that the students make a record of their readings and that perhaps a graph can be made to provide a picture of the movements of the pointer. Suggest also that they compare their tin can barometers with the control barometer. The readings from both barometers can be indicated on the same graph by using different colored pencils.

Ask the students if they can think of any factors which might affect the accuracy of the barometer. During the ensuing discussion, bring out an empty soft drink bottle with a deflated balloon over the open top. Set the bottle with the balloon into a pan of hot water. Be careful not to give the students any visual clues to the temperature of the water.

In a few moments, the balloon will become partially inflated and upright—a result of the warming of the air in the bottle. Then, ask the students a series of questions: Why did the balloon behave as it did? What do you suspect happened inside the bottle? What can you suggest about the condition of the water?

### Let the Students Suggest Solutions

Avoid the use of the word "temperature." Eventually, the students will suggest that the temperature of the air inside the bottle might have caused the balloon's *rigid condition.* Ask them how temperature might have affected the operation of their barometers. Some student will suggest that perhaps a record of room temperature should be kept in addition to the barometric readings. You should suggest the following questions: Will we be able to keep it on the same graph as the barometric readings? Can we make it on another sheet of thinner paper and to the same scale so that the temperature graph could be an overlay of the barometric graph? If they suggest temperature, question the relationship between temperature and the tin can barometer reading. As the temperature in the room rises will the barometer give a greater or lesser reading? Whose barometer do we think will show the greatest activity if temperature is a factor? Will the ones in the south window show more activity or will those in the north window? What about the ones next to the heater? Are any of those in the window made of dark-colored cans? Light-colored cans? What would be the results if we made some pointers longer (from can edge to scale) than others? Could we use this device as a thermometer?

Mr. Ruchlis' article has done a service to science instruction and has opened a new activity to teachers who want their students to think, observe, record, draw conclusions, and manipulate variables.

# Shadows

**MAYON R. ATHERTON**
First Grade Teacher
Calhoun School
Minneapolis, Minnesota

"I can step on your shadow," said one of the boys as the children started toward the building after the recess period.

If you are a primary-grade teacher, you have heard this statement made many times. But, have you ever capitalized on it? Do you see the possibilities of teaching about light, sun, and measurement by using children's shadows? Or have you used this interest in shadows to help your students learn how to record data, keep records, and find out about the seasons and time?

When the boys and girls returned to the room, they were asked what they thought caused shadows. The children came forth with many theories—many of which were excellent. They were asked to think of an experiment that could be performed in a classroom which would show how shadows were caused. One youngster suggested that the lights be turned on and this would produce shadows. Another suggested that the room be darkened and the filmstrip projector turned on. Then have a student walk through the beam of light coming from the projector. The children concluded that in order to produce shadows you have to have some type of light, and that light has to be partially blocked. They were not told this but arrived at this conclusion by themselves.

During the next recess period, some of the children noticed that no matter which way they ran or jumped their shadows always pointed in one direction.

### Another "Teachable Moment"

One of the children was asked to stand on the home base of the kickball diamond. The spot where she stood was marked carefully since she would have to stand in the same spot again. The edge of her shadow was marked. This event took place at 9:45 a.m. At 11:30 a.m., the class repeated the experiment. The shadow now pointed in a different direction. At 2:15 p.m., the experiment was repeated and the shadow pointed to still a new direction.

By use of a large globe and a five-cell flashlight (a filmstrip projector could be used in place of the flashlight), the teacher demonstrated to the class why the shadow pointed in different directions. First she glued a small plastic figure onto the globe, at the approximate latitude the school was located. A flashlight was arranged in such a manner that the brightest part of the beam of light was shining between the Equator and Tropic of Cancer. The light source remained stationary throughout the demonstration as the globe was rotated. The plastic figure remained stationary, but the direction that the shadow pointed changed as the globe was turned. Some of the children pointed out that the size of the shadow changed.

At 9:30 a.m. the next day, on the school playground, the entire class lined up with the shortest pupil first and the tallest last. Photographs were taken of the children and their shadows in September. The same procedure was followed in October, November, December, and January. Shadows were measured and each time a picture was taken. What do you think the class found out? Why not try it yourself?

A study of shadows can lead one into the use of a compass to find direction. It can make students aware of the setting and rising of the sun and its position in the sky at different times of the day. Measuring the length of the shadows can help to introduce graphs. Finding the difference between the length of shadows can help in the teaching of addition and subtraction.

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There are many teachable moments similar to this one. If you have one, why not send it to: the editor, *Science and Children*, NSTA, 1201 Sixteenth Street, N. W., Washington, D. C. 20036.

# MOON MODEL

**JOSEPH A. SMERTNECK**

General Science Teacher
Theodore Roosevelt Junior High School
Williamsport, Pennsylvania

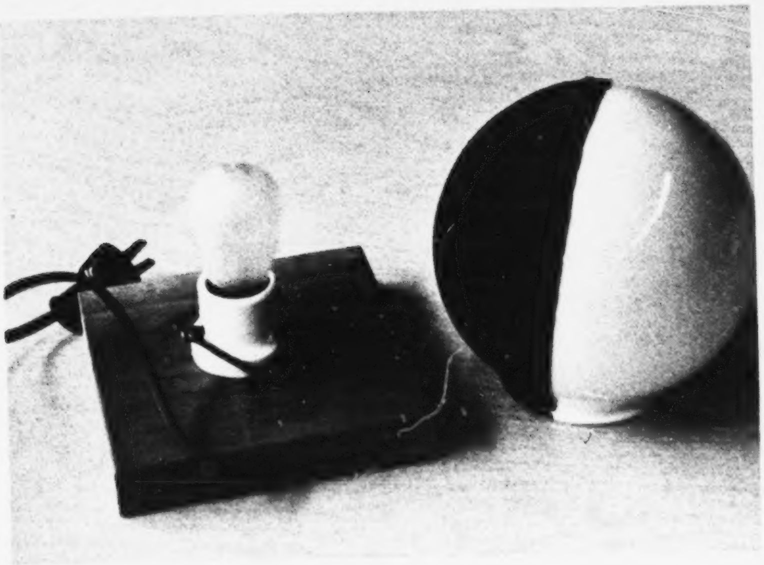


FIGURE 1.

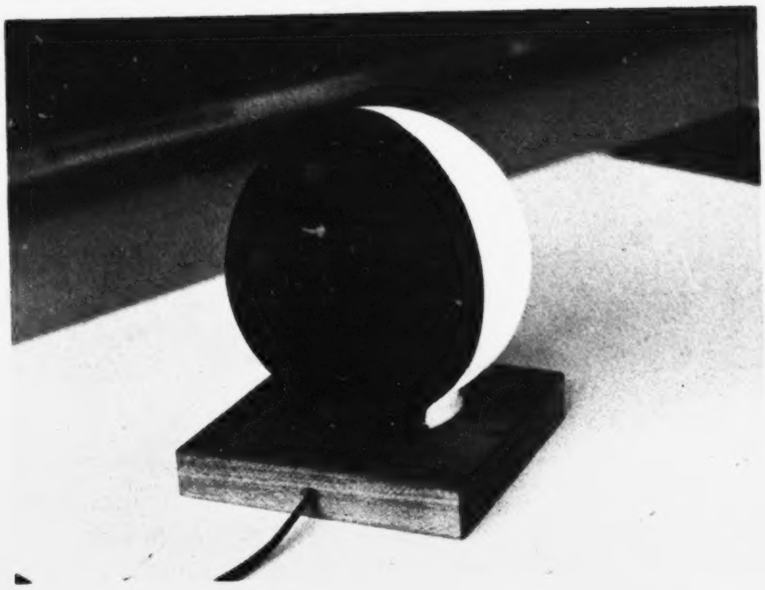
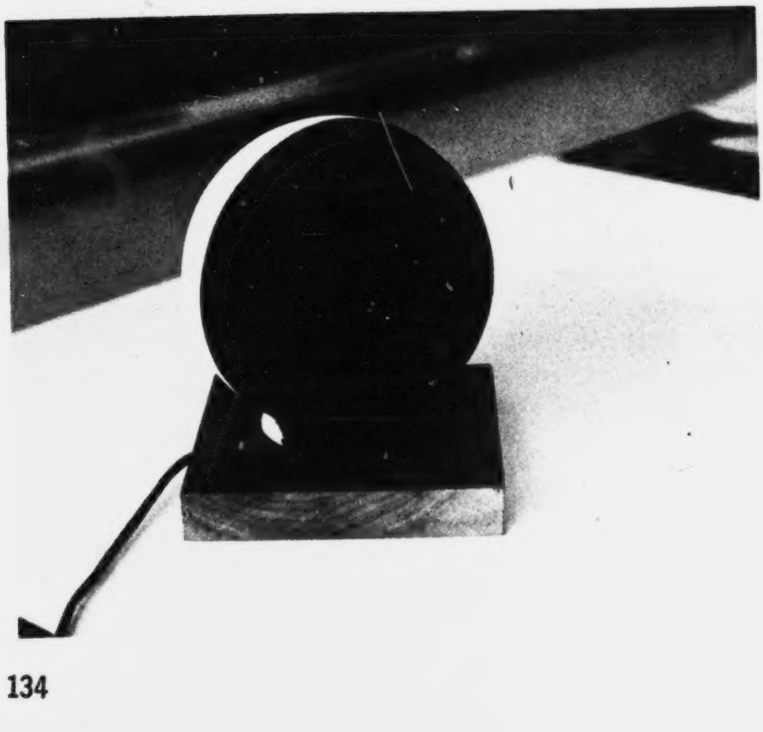


FIGURE 2.

FIGURE 3.



The simple, easy to construct, device pictured on this page has proved to be very helpful to me and my students when we are studying the moon. All of the materials required to build it can be purchased at the local hardware store.

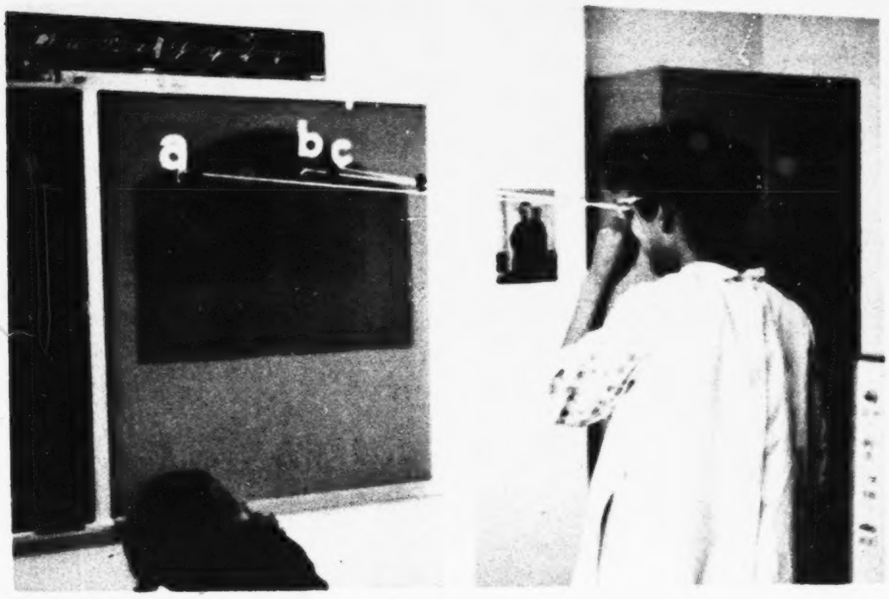
Figure 1 shows the component parts. A piece of wood about five inches square is used as a base. A cleat type of socket is attached in the center of the base with wood screws. An electric cord of any convenient length should be attached firmly to the connections on the socket. A globe of the frosted glass type generally used on porch lights should be placed over the socket and bulb.

Half of the globe is painted black to prevent light from shining through. I have used tempera water paint and found that it works well (regular paint would be more durable). Keep the bulb small—15 to 25 watts is sufficient—to avoid undue heating of the globe. When placed in operation, it is obvious that only half of the globe will be illuminated.

Figures 2 and 3 show the model in operation with the lighted surface simulating the illuminated surface of the moon. The effect is very dramatic in a darkened room. One point that should be emphasized is that the moon is visible only by reflected sunlight and is not self-illuminating like the model. By turning the base to allow various parts of the lighted surface to face the class, all phases of the moon from new to full can be demonstrated.

After you have demonstrated the phases of the moon, place the model in a position so that it is viewed by the students from several different angles. Have some of the students sketch on the blackboard the lighted surface as they see it. They will be amazed at the variety of sketches that appear. This demonstration can serve as a lesson to illustrate how any object appears to change shape depending upon the viewpoint of the observer.

# How Far The Stars?



**DOROTHY HENDERSON**

Science Resource Teacher
Montgomery County Public Schools
Rockville, Maryland

At times, children acquire many misconceptions without teachers being aware of what is taking place. One of the reasons for this, is that the subjects involved have been discussed in class until it appears that the students have mastered the material. Many times, the material presented appears to be obvious, obvious to the teacher with his many years of training and experience, but not obvious to the elementary school student. This point was brought home to me in an astronomy unit last fall.

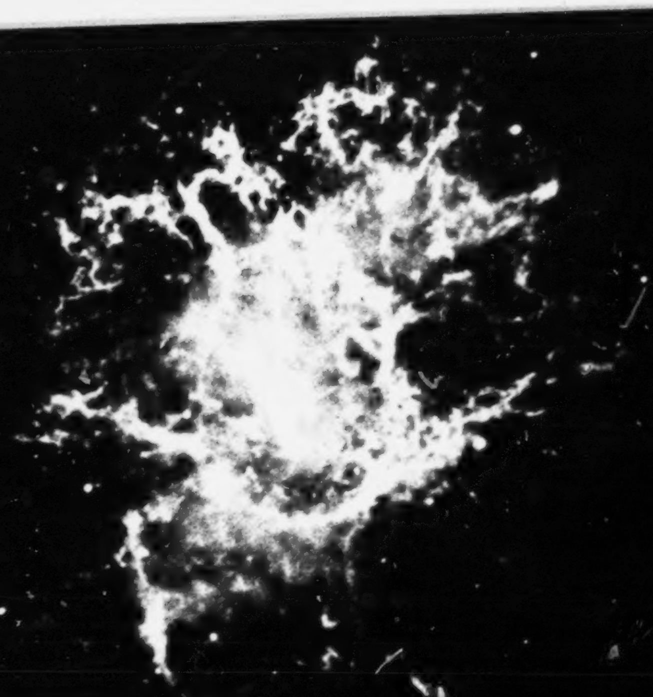
The class had been studying stars and constellations. I asked some of the boys and girls to make models of constellations which could be attached to the light fixtures in our classroom. Other members of the class made drawings of some of the better-known constellations. The children borrowed a ladder from the custodian and started to tie their models to the light fixtures. All was going well until one of the students said, "But, it's not even." I looked up at the models and saw that all of the star models were being hung about 8 inches from the fixture. At this point, I asked the children why they wanted all of the "stars" to be even. They replied that that was the way the stars appeared "on" the celestial sphere. Further questioning revealed that they actually thought that all of the stars were the same distance from the earth. We had discussed light years, and that the light from some stars took longer to get to our planet than from other stars. I thought that the students understood that this proved the stars were not all the same distance from us. It was obvious to me, but . . . *A Teachable Moment.*

Somehow, I had to get the idea across to the students that the stars, although they appear to be the same distance away, are actually great distances apart.

## Star Patterns

I had to think of a way to demonstrate that the stars appear in patterns in the sky and retain their apparent relationship regardless of the distance from the observer (within his present limits). The simple device pictured on this page helped me to illustrate this point.

I attached several strings to the bulletin board at eye level. Each of the strings had a bead or some other object (representing a star) on it that could be moved forward or backward. By moving the beads forward or backward, it was possible to show the students that regardless of their position on the string, all of the beads appear on the same plane against the background. This made it clear to the students that even though the stars in the sky appear in patterns that make them seem to be equal distances from the observer, they may be millions of miles away from each other.



JOSEPH MARON JOSEPH
Director, Secondary Curriculum
Public Schools
Chester, Pennsylvania

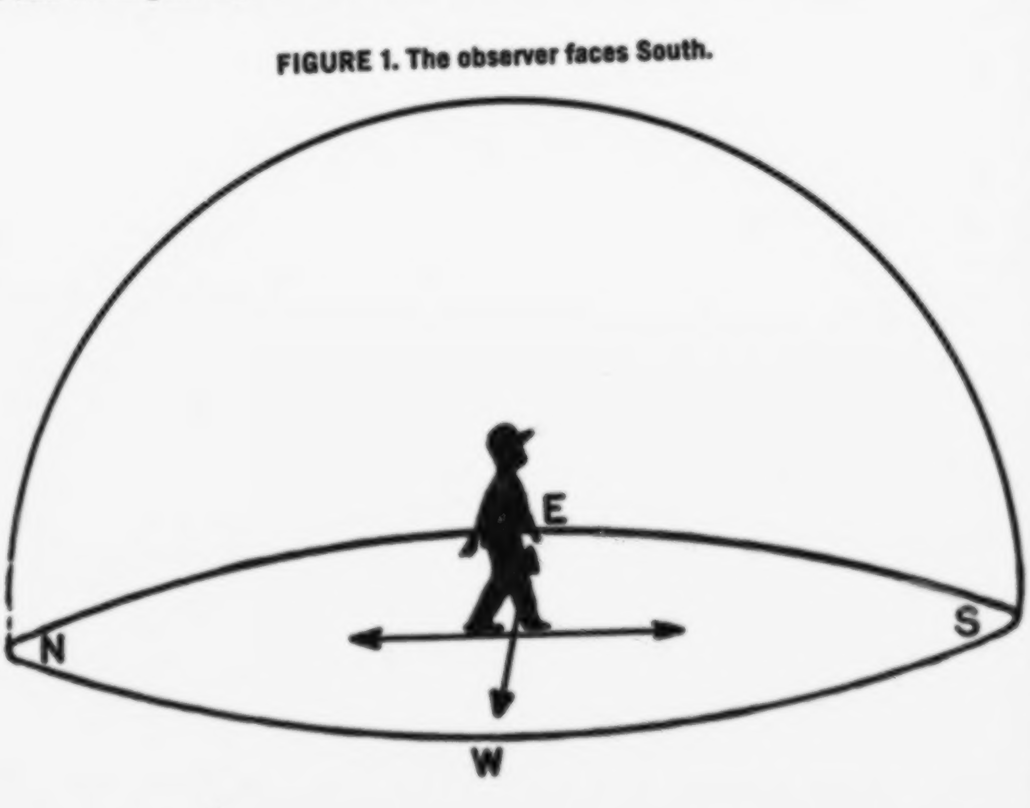
# Can We Take Astronomy Outdoors?

Astronomy, a study of the skies — this phrase should make every teacher think and evaluate the way he teaches this subject. Do he and his students study the sky, or do they just sit in the classroom, study books, and never look at the sky especially after the sun has set over the western horizon. In order to make a study of astronomy meaningful, young boys and girls should be taken out of doors for a look at the nighttime sky.

There appear to be two barriers why students in the elementary school do not study the sky out of doors. The first barrier is an obvious one—the subject matter, namely the stars and planets (except for the sun), are available for study only at night. This makes it impossible for the teacher to provide his class "first-hand," direct, sensory experience during the available class time.

The second barrier is the method by which astronomy—constellation identification, in particular—has been taught. Students are usually asked to look at large sky maps (which have all of the constellations of this hemisphere printed on them) and pick out a certain one. The student is now told to hold the map over his head in the correct compass direction, with the thought that the

FIGURE 1. The observer faces South.



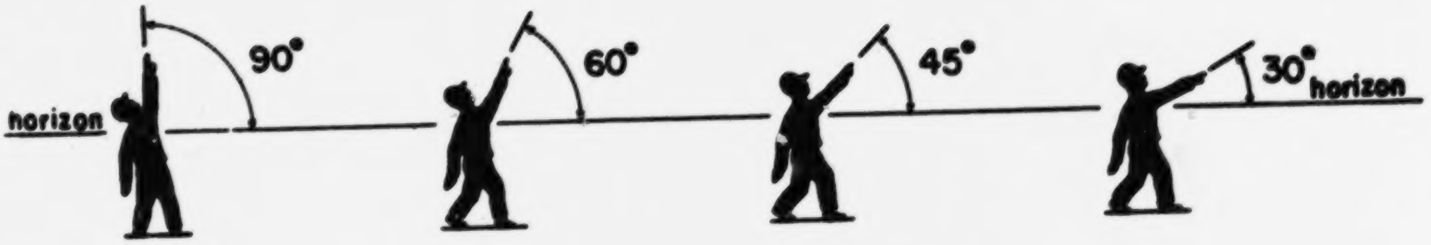


FIGURE 2. The observer measures altitude.

child pictures the map as a real sky and can go out of doors that evening and locate the chosen constellations. This has been the method of learning how to identify and locate constellations and/or stars for years, and one of the reasons that few of us are aware of where the constellations are located.

In this article, I will attempt to overcome the barriers mentioned above and show you how to study the nighttime sky in the daytime classroom. Several suggestions will be offered which, I trust, will prove practical for the elementary teacher to include in his unit on astronomy, especially constellation study.

### Face and Point

All methods of constellation study should begin with an orientation and proper use of the compass. The user of a star chart or map *must* know and be able to interpret correctly at least eight (8) points of the compass. How to do this in the classroom offers somewhat of a problem to the teacher. A good starting point is to test the double action expression, "face and point."

"Face and point" to the picture on the wall, or to the tree in the school yard can be mastered easily by the elementary school pupils, but "face and point" to the North Star presents another problem. In order to solve this problem, draw a compass correctly aligned to true North on the classroom floor. The drawing may be permanent or temporary. Another method which can be used is to mark four pieces of cardboard, about 6 x 9 inches in size, N, E, S, and W, respectively. Lay these marked cards on the floor (correctly oriented) in a radius of several feet. Have each child stand in the center of the floor compass and "face and point" to objects in the room by giving him a specific compass point to follow. (See Figure 1.*) After each child has had an opportunity to "face and point," the teacher asks the class to do this simultaneously.

The next step that has to be taken is to develop the floor compass into an *azimuth* (meaning *horizon*) scale. You may recognize this word as being the last part of the contracted word, *altazimuth*. Instead of using the names of the compass points (e.g., Northeast), or their abbreviations (e.g., NE) divide the classroom compass circle into points designating degrees. The horizon circle (the azimuth) has its zero point, 0°, at the North, continuing in a clockwise direction; East is 90°; South 180°; and West 270°.[1] It is now possible to use these numerical values to find direction. How to mark the converted floor compass with azimuth points is left to the ingenuity of the teacher. The children can now be trained to use this scientific-direction system.

After the boys and girls have developed self-reliance and can "face and point" to terrestrial objects quickly and accurately, they are now ready for the second phase of the altazimuth system. That is to find an object which is above the floor or horizon by its angular height or *alt*itude. For example, a picture of George Washington hanging eight feet above the floor on the wall, now is measured as being so many (35°) degrees in altitude above the floor or eye level.

At this stage, the teacher asks the boys and girls to imagine that they are outdoors, looking up at the sky dome. If weather conditions permit, the class should be taken outside to illustrate the next step. An observer, sweeping his gaze from the horizon to the point overhead (the point directly overhead is called the *zenith*), completes an arc of 90°. You can then teach the class some arithmetic by asking them why this arc is called a quadrant. All celestial objects have at any one moment an altitude ranging from 0° to 90°. (See Figure 2.)

### Altazimuth

Have each child stand "in" the center of the classroom compass and respond to the directions in both altitude and azimuth (altazimuth), given by the teacher. For example, "John, face and point to (an object selected by the teacher to coincide with these measurements) azimuth 55°, altitude 60°. What is the object?" (Outdoors, at the latitude of Chester, Pennsylvania, at approximately 9 p.m., in October, these coordinates are the face and point directions for the constellation Perseus, the Hero.) Each child could be asked first to try and locate an object in the room using this coordinate system. Obviously, the teacher must select an object either on the ceiling or high on the classroom wall. After you are satisfied that your students have mastered the altazimuth method of locating objects, it is now time to transfer the activity outdoors. Admirable as they are, solar system projects and similar indoor displays do not contribute to purposeful observation of the night sky. A crocus can be pointed out—why not a star?

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* Figure 1 and Figure 2 are taken from *Point to the Stars*, Joseph Maron Joseph and Sarah Lee Lippincott, McGraw-Hill Book Company, New York City. 1963. p. 20-21.

[1] Astronomers use South as the zero point, 0°.

The face and point technique can be used to permit the teacher to show all pupils how they can use this method when he is not with them. The knowledge and background gained from the classroom floor must be transferred to the child's yard, garden, or rooftop. Have each child draw a map, correctly oriented, to his neighborhood street or home plot. This map provides each child with a non-manned guide, which he can use as his learning tool when he works out home assignments in astronomy.

Students could be assigned to locate and learn about the (a) constellation "of the week," including its mythology; (b) the planet "of the week"; (c) the current artificial satellite that is visible in the area; (d) a selected star, for study of its color, temperature, and size; (e) the naked-eye nebula in Andromeda.

Many other topics of study could be worked into the curriculum for the upper elementary grades, and continued into the junior high and senior high school. All of these concepts, however, should have their roots in direct observation of the celestial objects at night.

How long should a pupil spend on learning to use the "face and point" technique for star identification? The answer may be found by asking another question: When does the outdoor science teacher stop showing pupils how to be alert to the first robin, or the autumn flight of migratory birds? The answer is only when the pupil is successful in observing these events on his own, so it is in astronomy. When the pupil can find his way without a guide, give him new challenges and permit him to be independent.

# Facts and Figures

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In your study of astronomy, do not be distressed when you find that references do not agree upon the size of the planets, nor the distances they are from the sun. In fact, here is an opportunity for your students to do some thinking and research. You might:

1. Check many references and tabulate the figures each presents;
2. Check the copyright dates of the references, maybe some are quite old;
3. Check the authors, perhaps some are not as reliable as others;
4. Find out how great the differences are. Chances are they will be a fraction of one percent.

Keep in mind that when an astronomer gives a figure for the distance to Jupiter, let us say, he invariably says that there is a percentage of error. The truth is that astronomers are always trying to improve their measurements; trying to get closer to the truth. When figures are used by reliable authors, bear in mind that these are the best, the most accurate available at the time. Next year, or the year after, new instruments and new techniques may produce figures that are more precise.

Right now, the figures given in the chart are generally accepted for the diameters of the planets, and the mean distances from the sun; but, remember, they are subject to change:[1]

| | Equatorial Diameter | Mean Distance From Sun |
|---|---|---|
| Mercury | 3,100 | 36,000,000 |
| Venus | 7,700 | 67,000,000 |
| Earth | 7,927 | 92,900,000 |
| Mars | 4,200 | 141,500,000 |
| Jupiter | 88,700 | 483,400,000 |
| Saturn | 75,100 | 886,000,000 |
| Uranus | 29,200 | 1,782,000,000 |
| Neptune | 27,700 | 2,792,000,000 |
| Pluto* | 8,700?<br>3,600? | 3,664,000,000 |

* Different investigators arrive at quite different figures for the diameter of Pluto. The problem here is great because of the distance of the planet, its dimness, and the absence of a satellite.

It would be a sad world if everyone accepted blindly the figures arrived at by someone else, and did not attempt to verify or improve knowledge already catalogued.

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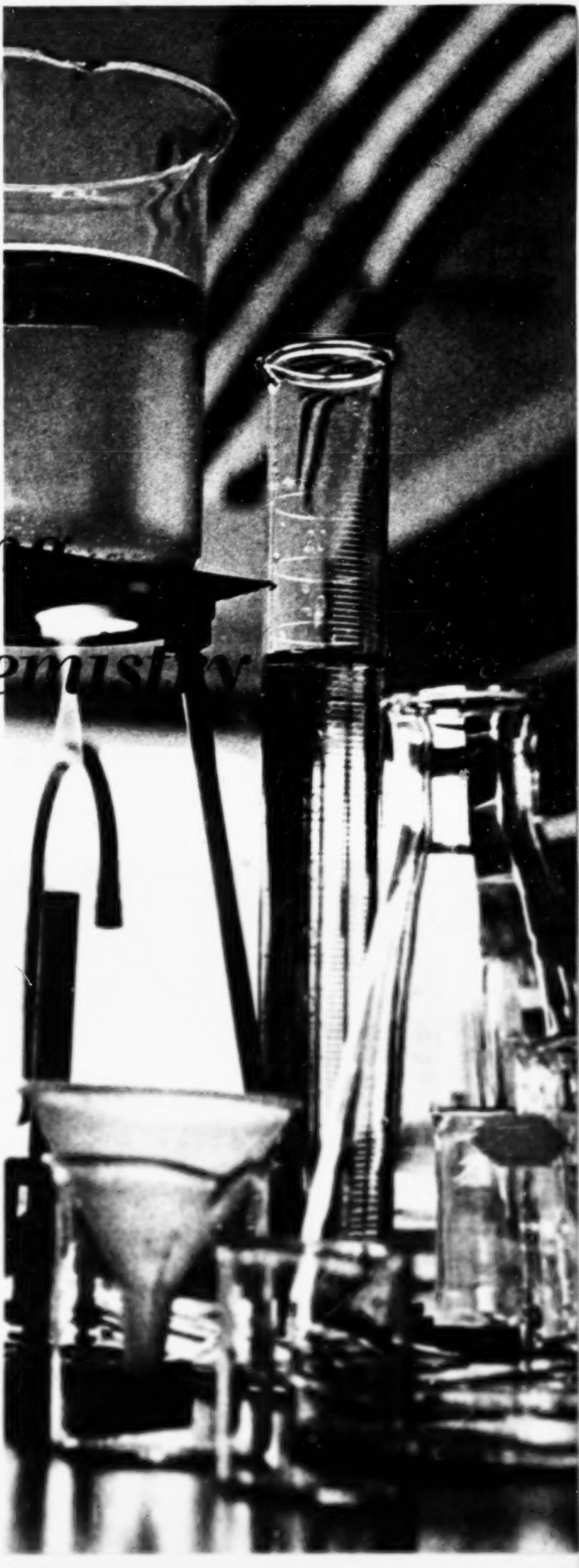
[1] *Explanatory Supplement to the Astronomical Ephemeris, the American Ephemeris, and the Nautical Almanac.* $8.40. Published by Her Majesty's Nautical Almanac of the United Kingdom and the United States of America. Can be purchased from the British Information Service, 35 Rockefeller Plaza, New York 20, N. Y. 1961.

RICHARD M. HARBECK
and
MARY BLATT HARBECK

# Investigating Chemistry



CHEMISTRY is a magical word to elementary school children. It conjures mental images of white-smocked scientists making exciting discoveries. Even the youngest school children have seen pictures in magazines and books of a chemist holding a test tube of some colored liquid as though he held the future of mankind in his hand. But often more fascinating than the chemist himself is his laboratory. The glittering glassware, burners, balances, and bottles of strange substances excite the imagination of boys and girls.

Even though overdrawn and glamorized, children's concepts of chemistry can serve to initiate new areas of learning and skill development. Children soon revise their "flash" and "bang" ideas about chemistry when they are involved in chemistry-related activities. Of more importance, good chemistry-related activities will not only contribute to the children's understanding of their world but will also provide countless opportunities

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*"Glittering glassware, balances, and bottles of strange substances excite the imaginations of boys and girls."*

for developing the skills necessary for scientific inquiry.

Chemistry—the science devoted to knowledge of substances, their composition, changes in composition, and interactions—should be included at the elementary school level. Many of the phenomena and processes which take place among both living and nonliving things can be understood adequately only in terms of their chemical nature. From the first grade (or even kindergarten) on, boys and girls should gain understandings of the composition and structure of matter, of chemical and physical change, and of the scientific method. Children progressively should be provided with more sophisticated problem situations in which to develop, practice, and apply the inquiry skills essential to the successful exploration of the world of matter.

What chemical concepts and principles should be developed during the elementary years? The answer to this question must be based on two considerations: (1) the specific content objectives of the science program and (2) the capabilities of the pupils. The latter consideration frequently places the elementary teacher in a dilemma. An elementary teacher with little or no formal training in chemistry has difficulty in determining which chemical concepts and principles are important and comprehensible to his pupils.

Listed below are a few guidelines and examples to use in selecting chemistry topics and activities that will develop the understandings or concepts generally considered appropriate for the elementary school years. The separation of concepts from principles in the following list is for convenience in use rather than as a reflection of a real difference.

*Chemical concepts which can be emphasized at the elementary school level:*

1. Substances can be identified and classified according to their special properties.
2. The properties of substances are of two kinds: physical and chemical.
3. All substances are composed of relatively few kinds of matter called elements.
4. Because of their consistency in behavior, chemical processes can be predicted by descriptive statements known as laws, principles, and hypotheses.

*Chemical principles which can be emphasized at the elementary school level:*

1. Chemical compounds have definite compositions by weight.
2. During ordinary chemical reactions, matter is conserved; *i.e.*, there is no loss or gain in weight.
3. Energy is involved in any chemical process or reaction, and during any process or reaction, the total amount of energy remains the same; *i.e.*, the energy is conserved.

Each of the above statements implies a whole range of ideas. For example, the first concept listed—that having to do with properties—implies a consideration of the states of matter (solid, liquid, and gas) as well as the use of both direct and indirect methods of observation. The first principle listed implies that there must be consideration given to the atomic and molecular structure of matter. It is through the learning of the implied "facts" and basic chemical ideas that pupils will develop a useful comprehension of the larger concepts and principles.

### Process Skills

Some examples of activities which will not only contribute to the content objectives in the teaching of chemistry but also provide suitable opportunities for process skill development are given later in this article. First, the kinds of process skills that the study of chemistry can develop need to be identified. These skills, which can be developed only as pupils work directly with substances, are:

*Observational skills*
- Description of gross characteristics
- Comparison of characteristics
- Direct measurement
- Indirect measurement
- Detection of changeable qualities

*Problem identification skills*
- Application of previously learned knowledge
- Asking of pertinent questions
- Identification of possible relationships

*Hypothesizing skills*
- Development of alternative answers to problems
- Development of hypotheses as declarative statements
- Use of concepts and principles in making predictions of phenomena

*Design and laboratory skills*
- Use of materials and equipment to test hypotheses
- Manipulative skills in handling of equipment
- Applications of concepts, principles, and facts

## Chemistry Activities

### First and Second Grades

During the first and second grades, boys and girls can be provided with opportunities to develop their observational skills of description and comparison by examining the gross physical properties of a wide variety of substances. Such properties include state (solid, liquid, or gas), color, texture, and form (crystalline, powdery, metallic, etc.). In some cases, pupils can also be expected to make rough judgments with respect to density ("this is denser than that") and simple chemical properties ("paper and wood burn, stones and nails do not").

Pupils can be provided with a variety of common objects and asked to sort them according to their common characteristics. A collection of such objects should include stones of different colors and textures, metallic objects (nails and copper wire), bits of glass (without sharp edges), and samples of crystals (pieces of rock salt), wood, and plastic. After the children have sorted the collection into different piles, try to have the pupils explain what properties distinguish one pile from the others. Once pupils have had some experience in identifying properties, they should learn about the special properties common to each of the three states of matter.

#### Air Is Matter

That air and other gases are matter the same as solids and liquids is one of the first concepts pupils must gain. Have the children observe a number of solid objects to try to identify the one common property. Some guiding questions will probably be needed. Once it has been decided that all of the solid objects seem to take up space, ask pupils to observe a number of containers of liquid (colored water, oil, soap). Ask them if liquids also have the property of taking up space. When general agreement has been reached that this is true, ask the class if "taking up of space" might be considered a general property of substances (or matter). If the statement is true, then it might be used to test things which are neither solids nor liquids to determine whether they are substances (matter). Such a substance is air. With careful guidance, even first or second graders can be led to suggest that if air is a real substance, it should take up space. This is a real hypothesis and can be tested. Several traditional elementary school science demonstrations can be used to test the hypothesis, such as placing an inverted glass in a pan of water or forcing the air out of a plastic bag.

Through such demonstrations, pupils learn about air as a substance by first developing a hypothesis based on their own observations of solids and liquids. Then, they design an experiment to test the hypothesis. The procedure affords the pupils an opportunity to develop and practice process skills.

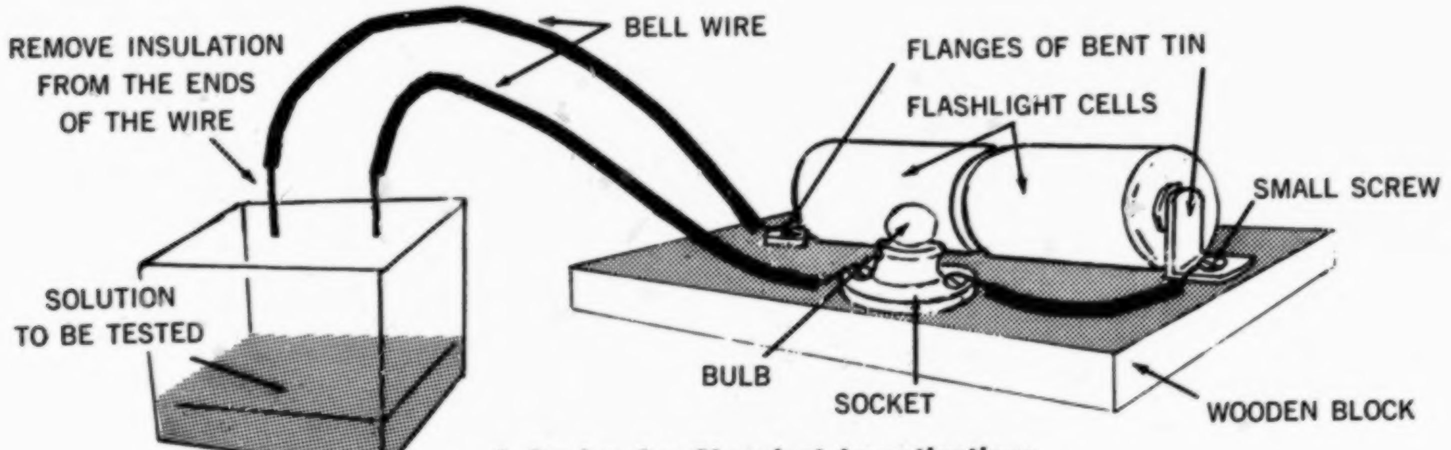
#### Some Substances Dissolve in Water

Before the end of the second grade, pupils should be given an opportunity to discover that some substances dissolve in water while others do not. The teacher can suggest to the pupils that some properties of substances cannot be detected directly by observation. To explore "hidden" properties, the pupils should be provided with samples of substances, some of which are soluble. Have them mix these samples in containers of water and encourage the pupils to ask questions about their observations. These questions can be the basis for further experiments with solutions.

### Third and Fourth Grades

By the time pupils are in the third and fourth grades, they can begin making simple measurements and start gaining some understanding of chemical and physical processes and of the structure of matter. The words "atom" and "molecule" are introduced and become part of their vocabulary.

In addition to extending their knowledge of gross physical properties of substances through direct observation, pupils should begin to make measurements of these properties. The concept of "density" as it



A Device for Chemical Investigations

applies to solids, liquids, and gases can then be developed through actual measurement activities. Once pupils have learned how to estimate density by using rough scales and simple units of weight and volume, they can start testing a few hypotheses. For example, if a pupil hypothesizes that a large iron nail will have about the same density as a large iron washer or other iron object, have the class test it.

### Chemical Changes

In the intermediate grades, pupils should learn to distinguish between common physical and chemical changes and the means by which such changes can be observed. For example, pupils should discover that some chemical changes result in changes in colors of substances. These color changes, in turn, can be used to detect the properties and changes which take place in other substances. Weak solutions of vinegar, bleach, and ammonia water can be tested with strips of litmus paper to initiate this kind of activity. Later, pupils can test other colored substances such as grape juice and water in which red-cabbage leaves have been boiled.

After pupils have had an opportunity to consider the relationship of atoms and molecules to the structure of matter, they should be able to develop a number of simple hypotheses which can be tested to confirm this relationship. Are atoms affected by chemical change? If not, it can be hypothesized that if atoms are not changed during chemical reactions, then none should disappear. If this is true, then, the total weight of the substances involved in a chemical reaction should remain the same. This can be demonstrated by mixing a weak solution of silver nitrate and sodium chloride in a container, sealing the container, and placing it on one pan of a beam balance. The ensuing chemical reaction will not cause the balance to change.

### Fifth and Sixth Grades

Fifth- and sixth-grade boys and girls should be provided many opportunities to become adept at using simple pieces of laboratory equipment, measuring instruments (graduates, balances, thermometers), and at handling chemical substances. Activities deliberately designed to pose problems of a chemical nature will give pupils experience with the use of such equipment. For example, use some wire, a flashlight bulb, and two flashlight cells to construct the simple piece of apparatus shown in the diagram. Note that one of the wires from the bulb and one from the cells are not connected. Have the class observe the bulb when these two wires are dipped into a container of pure water (do not use tap water—use distilled water or water obtained by melting frost from a refrigerator or freezer). Next, dip the two wires into a table-salt solution. Then, dip the two wires into a sugar solution. Finally, have pupils test solutions of other substances including vinegar and ammonia water as well as alcohol and glycerine. Have the class search for characteristics common to those substances which, when in solution, will cause the bulb to light.

Emphasis, both direct and indirect, should be placed on making, analyzing, and interpreting measurements. Temperature readings of boiling and freezing points can be made. Also, the effect of different amounts of substances dissolved in water on its freezing and boiling points can be studied.

### Sources of Information

There are many sources of information and ideas about chemistry available to elementary school science teachers. Perhaps the most immediate and often enthusiastic source is the nearest high school chemistry teacher. Most high school chemistry teachers, especially if in the same school system, will be glad not only to help supply ideas, but will also loan essential bits of equipment. Sometimes, nearby college chemistry departments have staff members who are also willing to assist busy elementary teachers.

In addition to personal contacts, ideas can be gleaned from a wide variety of elementary books on chemistry and laboratory experiments. Weekly and monthly periodicals directed to junior and senior high school students also can be good sources of information and classroom activities.

# A Biochemical Fuel Cell

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Fuel cells are an interesting, relatively new source of electric energy. Students who are already familiar with several sources of electrical energy such as the common dry cell,[*] the dynamo, and the storage cell will be able to grasp some meaning of *fuel cell.* In terms of students' knowledge of the word "fuel" and the term "cell," it is not too difficult to develop the concept "fuel cell."

## A Classroom Project—Making A Biochemical Fuel Cell

At the intermediate elementary school level, a classroom project of constructing a biochemical fuel cell can be effective in helping pupils understand their operation. Before beginning the project, the students should understand that the "fuel" in a fuel cell is actually used up (much as fuel is consumed in the operation of a furnace) as opposed to the chemical cell or battery in which no such action truly takes place. The students also should learn that the fuel cell is not *recharged,* as can be the storage cell, but is refueled much like a furnace is refueled. Through the addition of fuel, the fuel cell continues operation. The storage cell, on the other hand, often must be taken temporarily out of operation and subjected to an outside energy source to be recharged. Depending upon previous understandings, the students can be brought to understand the nature of the operation of the fuel cell. While some students will probably continue to understand the operation in terms of stoking a furnace, others will develop some understanding of the chemical process of oxidation which takes place.

The complete chemical and biochemical reactions of this type of biochemical fuel cell are far too complicated to teach at the intermediate-grade level. This, however, need not be considered an indication that the project is not a worthwhile class endeavor. Most elementary school science has aspects that are not appropriate at any elementary-grade level. The success of our efforts often depends as much upon knowing what *not to* teach as what *to* teach.

*Materials:*

**Sawdust** (Approximately one quart)

**Water** (Rainwater or distilled water is preferred, but ordinary tap water can be used if boiled 10 minutes to remove the chlorine.)

**Plastic or glass container** (A clear refrigerator container 4x4x3 inches is preferred. If such a vessel is not obtainable, then any small glass container fitted with a plastic cover will suffice.)

**Plastic cement** (One tube)

**Asbestos** (One small sheet is necessary to divide the plastic container into two compartments of approximately the same size. One source of asbestos is old hot-dish pads.

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[*] Throughout this article, the words *cell* and *battery* are restricted to their proper meaning. The cell is the simplest unit in the electrical energy source. A battery is two or more cells operating in close conjunction. Upon first contact with these expressions, *cell* and *battery,* students are often prone to misuse the word battery as in the expression *flashlight battery,* which is more properly *flashlight cell.*

Hardware stores are often able to supply sheet asbestos at low cost. Be certain to obtain a sheet thin enough to be cut with a knife or scissors.)

**Tinned-copper wire** (Two 8-inch lengths of No. 22 wire)

**Plastic-coated copper wire** (Two 12-inch lengths are needed. No. 14 wire is perfect, but other sizes will function satisfactorily.)

**Friction tape** (One small roll)

**Stainless steel scouring pads** (Two without soap or cleanser)

**Fungus** (Nearly any of the wood-thriving varieties, such as bracket fungi, will serve adequately. Have the pupils locate and collect large quantities of fungus, which can be used in the construction of additional fuel cells. The pupils will discover that the best source of fungus will be old tree stumps, logs, and other rotting organic material on damp, warm days.)

**Algae** (Any green or blue-green pond algae is satisfactory.)

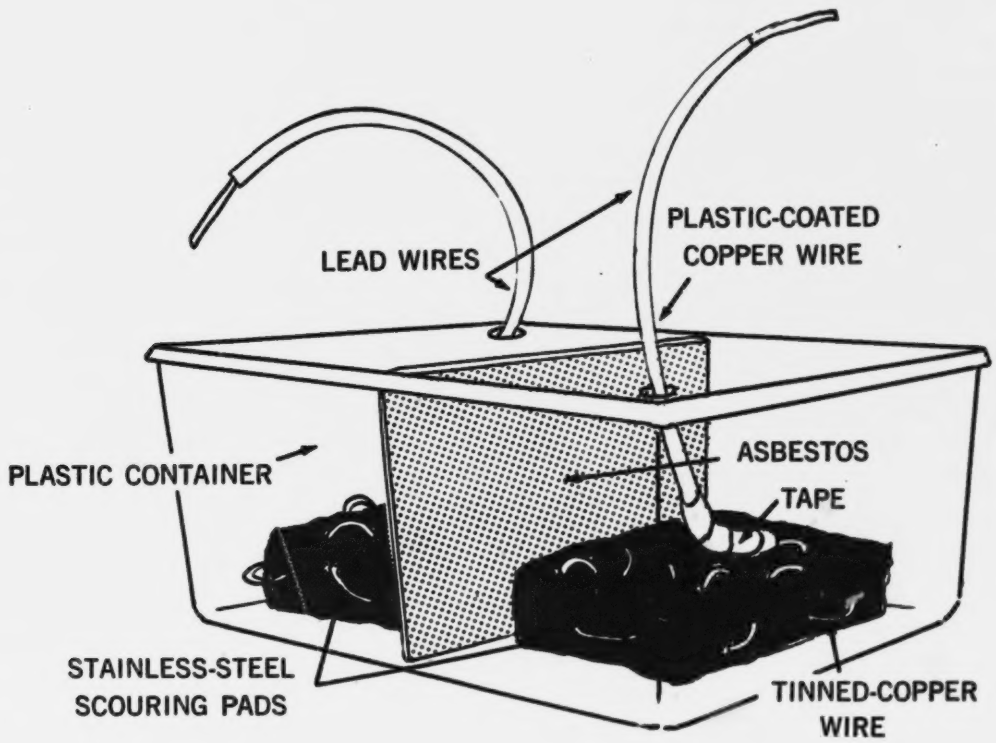
**Nutrient mixture** [To keep the colonies of fungi and algae active for use in the fuel cell, the following nutrient mixture is necessary for growth. Dissolve 8 tablespoonfuls of ordinary 8-8-8 commercial fertilizer in ½ gallon of rainwater. Then add 2 tablespoonfuls of commercial (agricultural) calcium carbonate and 4 tablespoonfuls of an organic substance, such as peanut meal, cottonseed meal, or blackstrap molasses to the mixture. Put a portion of this nutrient mixture aside for the algae. (Two teaspoonfuls of the nutrient solution added to the water in which the pond algae culture is living will keep it alive for two weeks.) Soak the sawdust in the remaining nutrient and, if facilities allow, boil this mixture for 15 minutes. This sawdust and nutrient mixture will be for the fungi.]

*Procedure:*

1. Assemble the container for the fuel cell by dividing the plastic container in half with a partition of asbestos. Affix the asbestos sheet into the container with several coats of plastic cement so that both compartments are leakproof. (The cultures of fungus and algae which will be placed inside must not mix.)

2. Make two holes in diagonal corners of the lid of the container with a *hot* nail or wire. The diagonal placement of the holes gives stability and utility to the assembly. The holes must be large enough to allow the lead wires to pass through. See the diagram.

3. Remove the insulation from both ends of the two lead wires. One inch of bare wire on one end and two inches on the other end will be adequate.



In order to reduce the internal resistance of the fuel cells (this concept of internal resistance need not be pursued with the class), No. 22 tinned-copper wire can be woven in and out of the stainless-steel scouring pads. When the wire is thoroughly woven into the pads, the No. 22 wire should be soldered onto the No. 14 lead wires. (A radio or TV repair shop may be willing to provide a soldering iron.) It is desirable to tape the connections to keep the uncoated ends of the No. 14 copper wire out of contact with the materials in the cell compartments. Copper is pathological (poisonous) to the algae as well as to the fungi. When both scouring pads are equipped with a soldered lead wire, bend the assemblies to fit into the compartments in the plastic container and pass each lead wire through the appropriate hole when the lid is placed on the container. The assembly should resemble an electrical cell, for there will be two electrical leads provided. (Students should be aware that cells have positive and negative leads and that two leads or terminals are required per electrical cell.) If you wish to emphasize the negative and positive aspects of the fuel cell, use the standard colors: a red (painted or plastic-coated) wire for the positive lead and a white wire for the negative lead.

4. When the assembly is dry and serviceable, the "fueling" operation may be undertaken. Into one compartment, add some algae and nutrient solution to approximately ¾ inches from the top. Check for leaks and make any necessary repairs with the cement.

5. Fill the other compartment with the fungus sample along with some of the sawdust that was processed with the nutrient solution to approximately ¾ inches from the top. The sawdust should be thoroughly wet with the nutrient solution.

6. **Both compartments should** be tamped and arranged so that the stainless-steel scouring pads (which now may properly be called electrodes) are covered.

7. Within a few minutes, an electrical current can be detected with a voltmeter calibrated to tenths of a volt and having an internal resistance of at least 2,000 ohms. (It may be necessary to borrow such a voltmeter from a high school physics teacher.)

The compartment containing the fungus becomes the positive side of the cell; the algae side becomes negative. Voltmeters are plainly marked *PLUS* and *MINUS* or positive and negative. Due care should be exercised to instruct students to use the voltmeter properly.

If the sawdust, fungus (ground or broken into small pieces), and nutrient mixture are thoroughly mixed, the vigor of the sample will be greatly increased. After a few days of activity, the operation of the fuel cell will improve.

The algae sample must be kept moist with an adequate supply of the water from which it was taken. For water storage, use a large jar with a perforated lid.

Both algae and fungi samples will develop undesirable odors as the organic matter decays. It is a good idea to ventilate the classroom occasionally.

### Possible Problems and Projects

Problems that arise in this class project are usually caused by failure to have good electrical connections; failure to wait long enough for the fungus and algae to become activated; cross-contamination or mixing of samples through leaking compartments or sloppy work in filling the assembly; or dead samples. None of the operations in this project are dangerous! Only the normal classroom precautions need to be observed.

Teachers who are interested in working with this project or projects of a related nature will find it desirable to secure considerable reading material for their students and themselves on the general topic of fuel cells. Any reader who wishes to obtain more information on fuel cells is encouraged to consult the suggested literature and is invited to communicate with one or all of the authors.

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# An Electrostatic Charge Detector

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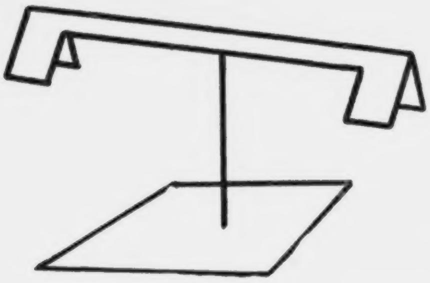
The equipment most commonly used for the detection of electric charges in the elementary school are pith balls and the electroscope (aluminum or gold-leaf type). If these items are in short supply or are not available in your school, why not construct a simple detector of your own? The cost will be negligible, and the students may well enjoy constructing their own equipment. A homemade detector I use for demonstrations in my classes is anywhere from five to ten times as sensitive as pith balls. Of course, quantitative study of charges with simple equipment is difficult.



*Procedure:*

(The dimensions given below are not absolute; but remember that the less paper used, the more sensitive the detector will be.)

1. From any kind of paper, cut a rectangle 1 x 3 inches.

2. Fold the rectangle in half, parallel to its length.

3. Cut out an area 2½ x ⅜ inches from the center of each side of the folded paper. (See figure.)

4. Insert a pin through the center of two or three one-inch squares of paper, thus making a "stand" to hold the pin with its point upright.

5. Carefully balance the V-shaped strip of paper on the point of the pin. (The student who sticks the pin through the paper will soon find out that the apparatus will not work!)

Plastic combs, pens, and small rulers are among the easiest articles to charge by rubbing with a cloth. When such an object is brought near one end of this detector, the paper will pivot around, and, compass-like, point to the source of the charge.

The detector is very sensitive to drafts and air currents. To overcome this problem, smaller models can be constructed and glass tumblers inverted over them. Although they still work, these detectors are less sensitive because of the added amount of shielding by the glass.

## For Grades 2 and 3

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What do you see?

# Convex Lenses

**Overview:**

This exercise deals with the various materials of which lenses are made and the ways in which light is bent by different shapes of convex lenses.

The study of lenses can be approached through a spirit of inquiry. Pupils can do various simple experiments with convex lenses, from which questions will develop both by the teacher and the pupils.

**Materials:**

1. Several variety store magnifying glasses. These must be circular and they must be glass.
2. One or more rectangular reading glasses.
3. Several plastic convex lenses.
4. Some pieces of stiff cardboard.
5. A sheet of waxed paper.
6. A glass of water and a sharpened pencil.
7. A watch glass from the high school science department.

**Advance Preparation:**

1. Place one of the variety store magnifiers on the cardboard, and trace around it. Cut a ¾-inch circle out of the round part of the drawing. Then cut the whole design from the cardboard. At this point, it will look like a peephole with a handle. Bend the handle up at a right angle. Make one of these for each member of the class. Apply glue to the bottom surface of each one away from the handle. Place each one, glue side down, on the sheet of waxed paper. Cut around each form and you now have a peephole covered with waxed paper.

2. Boil some water. This will drive the air out of it. Allow this water to cool. Then fill the watch glass with the water and put it in the refrigerator freezing compartment. When the water freezes in the watch glass, you will have an "ice lens."

**Teacher's Purposes (Understandings):**

1. Lenses can be made of any transparent material.
2. Lenses have at least one curved surface.
3. Convex lenses make things look larger.

**Procedure:**

Pass out the variety store magnifying glasses to the students and ask them if they know what it is called. Someone should say that it is a lens. Ask the pupils what they can discover about the variety store lenses. The various discoveries can be listed on the board as they are contributed. At least one pupil will remark on the curvature of the surface. It is hoped that some bright pupil will note that a lens is thick in the center and gets thinner toward the edges. If this is not discovered, the teacher should point it out. Several pupils will say that the lenses make things look bigger.

At this point, the teacher can pause to review the discoveries about lenses as listed on the board. The discoveries should include: (1) Lenses are circles; (2) They are made of glass; (3) They have two curved surfaces; (4) They are thicker in the center; (5) You can see through them; (6) They make things look larger; and (7) They are solid. If any of these items is missing, the teacher should add it with a brief explanation.

At this point, ask the students if all lenses are circles. If some pupil says no, proceed to confirm his contribution with the rectangular reading glass. If no denial is made, produce the rectangular reading glass, and ask if it is a lens. If some pupil says yes, have him state his reasons for calling it a lens. Then help him test his reasons and bring out the ideas of curvature and magnification. If no reaction comes from the pupils, ask if the material can be seen through. Is the surface curved? Does it make things look larger? Is it thicker in the center? Is it a lens?

Next, hand out the plastic lenses, and ask what they are made of and if they are lenses? Some of the pupils will say that they are lenses. The students should be able to tell why the piece of plastic is a lens. The plastic lenses can then be compared with the list. They are not glass, so the word "glass" will be erased from the list of requirements for lenses.

The teacher now asks if a lens can be made of a piece of ice. This is compared with the list, and it is brought out that the ice would have to:

1. have two curved surfaces.
2. be thicker in the center.
3. be seen through.
4. make things look larger.
5. be solid.

The "ice lens" is brought out of the school cafeteria refrigerator. Turn the watch glass upside down carefully, and the "ice lens" should come out into the hand. If it does not come out readily, hold it under running water for a second or so, watch glass side up. Have the pupils put the "ice lens" through the tests. This lens will have only one curved surface, but it will fit all other requirements. The teacher can then change the list of lens requirements to include "at least one curved surface."

The next question to bring up for investigation is whether the lens has to be solid or not. After hearing some contributions, the teacher can ask if a drop of water could be a lens. The pre-prepared peepholes of waxed paper are now passed out. Each pupil is asked to make a small dot on a piece of paper. The peephole should be placed directly on the dot as the dotted paper rests on the desk or table. The teacher then shows the pupils how to use the sharpened pencil to place a very small drop of water on the waxed peephole. (Place the sharpened pencil point sideways into a container of water. As soon as water collects on the exposed wood, transfer it to the paper. A few practice turns may be required.) By moving the peephole so that the dot may be seen through the drop of water or just through the waxed paper the pupil may observe the apparent change in the size of the dot. (The teacher must be sure that each drop of water is so *small* as to be almost spherical and that each pupil notices the magnification.) Is the drop of water a lens? The list is referred to and the drop of water meets all the requirements except that of being a solid. (The teacher may have to bring this out.) The word solid is then erased.

Going over the remaining items in the list, the teacher can emphasize that the class has learned the requirements of convex lenses. A convex lens must:

1. have at least one curved surface.
2. be thicker in the center.
3. be seen through.
4. make things look larger.

# Color Experiments

**HY RUCHLIS**

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Good science teaching is composed of many factors, and undoubtedly most teachers consider good equipment as an important teaching tool. Schools spend large sums on equipment, from test tubes to rolling laboratory tables. Most of the material purchased is important and useful in teaching science; however, much of it is never used either because the teacher does not know what to do with it or the equipment is not suitable for the elementary grade levels.

Careful selection of material can often overcome difficult obstacles to teaching and solve budget problems, too. A properly selected material can often help the teacher convert a difficult subject into a simple one.

As an illustration, consider the subject of color, which is generally considered part of the curriculum at practically all grade levels in the elementary schools. The starting point of such studies is the concept that white light is composed of all the colors of the rainbow. The prism may be trotted out and displayed. If there are enough for all children (a rare event) the prisms will be passed around, with frequent admonitions not to drop the fragile glass objects. The children look through their prisms and see colored borders on everything. Sometimes the borders look blue and sometimes red—it depends upon the position of the object being viewed and the direction from which light comes. The other colors are usually indistinct. There is a general feeling that white light might be composed of colors, at least that is what the teacher and the book tell them. It is a vague "take-it-on-my-word" approach, rather than a truly creative, discovery activity in which the children find out for themselves. Of course, if the teacher is quite expert, she may be able to project a spectrum on a screen and perform interesting demonstrations.

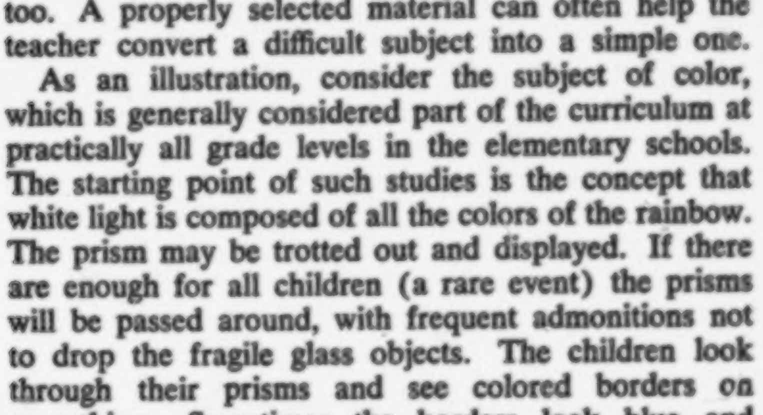

Figure 1.

### Diffraction Grating Material

Consider what a difference occurs when the newer "diffraction grating" material is used. A very inexpensive form of this material, available for a few cents per child, consists of thousands of fine markings in a transparent plastic. (Diffraction grating material may be purchased from any science supply house.) The effect of these markings is to break up white light into brilliant spectra far more vivid and intense than those produced by prisms available to elementary teachers.

With this material any teacher, even if she is untrained in science; can teach a truly exciting lesson in which the children can discover the facts about color for themselves.

The secret of success is to use a sharp line source of light (A in Figure 1) which the children view through diffraction gratings. A special light bulb with a sharp vertical line of light is placed on the teacher's desk. Each child viewing the vertical line of light sees several beautiful spectra with the colors clearly identifiable. In another arrangement, the "hand spectroscope" shown in Figure 2 provides a slit (B) at the front end of the tube (C). This device substitutes for the line filament bulb at the desk. The light source, a bright window or lamp (A), is viewed through the diffraction grating (D). This arrangement is more costly per pupil but has the advantage of providing for individual work without constant teacher direction.

### Primary-Grade Activity

Children in the first or second grade can easily discover for themselves, by actual observation, the order of colors in the spectrum—ROYGBIV—representing red, orange, yellow, green, blue, indigo, and violet. There may be some question about the indigo and violet, partly because incandescent bulbs produce little of these colors of light and partly because they are not clearly visible. However, the children can all clearly see the ROYGB portion, and in proper order.

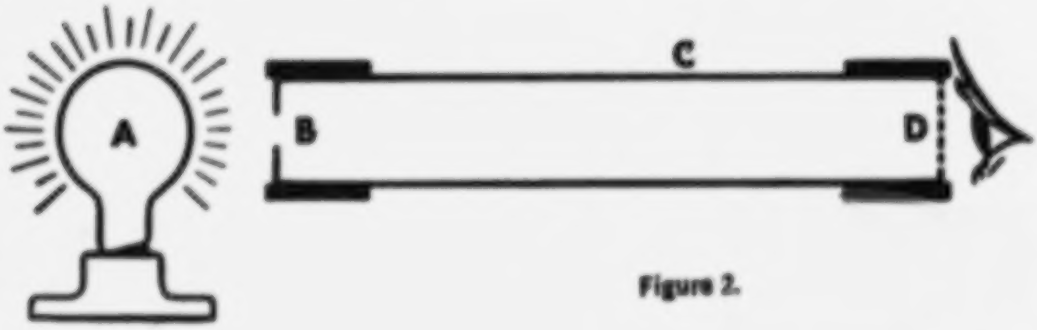

Figure 2.

### Intermediate-Grade Activities

At the third- and fourth-grade level, the teacher can interpose various transparent colored plastics or "filters" in front of the light source. Or, the children can do this themselves if they are using individual hand spectroscopes. Each child can then discover for himself that each color of plastic removes a specific color from the light. A red plastic cuts out practically all but red light from the spectrum, but some observant child may see a faint bit of blue in the spectrum. This brings up the difference between *pure* colors and the various hues and tints we observe in everyday colors, most of which are mixtures of various percentages of colored light. A purple or magenta-colored plastic will cut out the middle green and yellow portion of the spectrum, leaving the red and blue extremes.

### Upper-Grade Activities

At fifth- and sixth-grade levels the same diffraction grating can be used to observe bright lines in spectra produced by fluorescent lamps and neon signs. These bright lines are characteristic of the chemical elements in the gases of the tubes and serve to identify the specific elements. This fact is the basis of the spectroscope, one of the most useful of scientific instruments. Again, this may be studied by means of direct observation by the children using diffraction gratings. Basic understanding of what they observe is quite simple so long as one stays away from questions about how the diffraction grating works. This need not be an obstacle because most young children will be satisfied to know that the grating *does* break up white light into colors, even if they do not know *why*.

A more curious teacher can continue to explore the spectrum more intensively. For example, half-coated fluorescent bulbs are available in which the upper half is not coated with fluorescent material while the lower portion is. The children, observing the differences in the spectra (Figure 3) can learn something about fluorescence and the nature of ultraviolet rays.

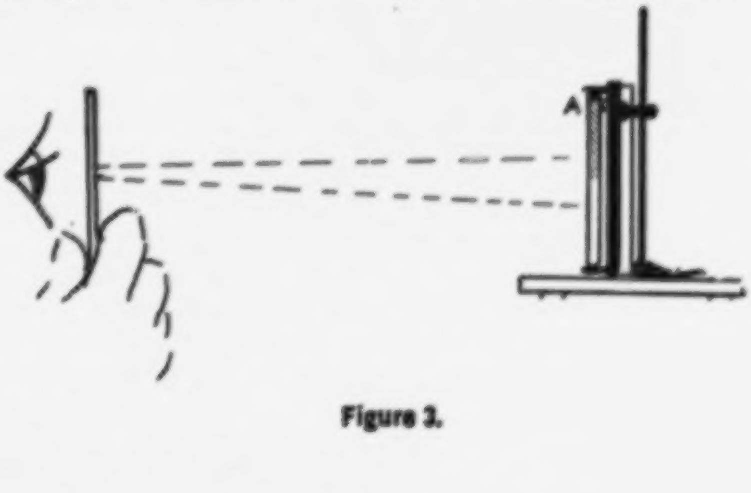

Figure 3.

This approach to color has also been used by some creative teachers to introduce lessons in art. Color theory taught in this manner provides a powerful bridge between art and science.

## Letters

### Extending the Scope of an Article

I am writing in reference to the article, "Color Experiments," by Hy Ruchlis in the December 1965 issue of this magazine. There are a number of points where the article can be expanded. The enclosed suggestions should be helpful to teachers:

1. The light bulb which is best for diffraction gratings is called a show-case bulb and should be unfrosted. An interesting invitation to inquiry is to ask the students why there appears in the spectrum two or more black lines perpendicular to the spectrum.

2. The upper-grade student can easily make a simple and inexpensive spectroscope by following the directions given by Companion, *et al. Journal of Chemical Education.* 39:147. 1962.

3. If a prism "breaks up light," can it be reversed to recombine light? Do not try it with diffraction gratings.

4. Diffraction and interference effects can be observed using phonograph records, fingers (the ridges which give fingerprints also function as a diffraction grating), a pinhole in aluminum foil, an overhead projector (colors are observed at the edges of the light which is cast), lines cut in carbon black (from a candle) or graphite which has been deposited upon a microscope slide (use

a razor and make the lines parallel; however, one line will work), oil on water, and children's "soap" bubble solution.

5. What is the effect of various colored cellophanes, solutions of food colors, and pieces of colored paper placed between the bulb and diffraction grating? Does blue cellophane absorb the blue line in the spectrum? One can also use solutions of various inks.

6. The student can grow his own crystals which can be cleaved into prisms. $NaBrO_3$ is suggested. Sources to consult are A. Holden and P. Singer, *Crystals and Crystal Growing*, Doubleday-Anchor Books, Garden City, N.Y., 1960, and E. A. Wood, *Crystals and Light*, D. Van Nostrand Company, Inc., Princeton, N.J., 1964. The latter book and an additional one describing some experiments with crystals and light are available from the Bell Telephone Company (consult your local business office). Bell also produces a kit which can be used to construct a polarizing microscope and has developed a crystal grower which can be purchased.

7. A simple prism may be made by taping three microscope slides together and filling the center with water. (Carefully tape the ends to prevent leakage.)

8. It is very easy to replicate Herschel's experiments which proved the existence of infrared radiation. One simply has the spectrum from a prism fall upon a piece of black paper. Thermometers can be used to show temperature difference or the rates of evaporation of alcohol can be utilized.

9. The upper-level student may want to find out if all "neon" lamps contain neon; *i.e.*, is the spectra the same for all neon lamps?

EDWARD W. KLEPPINGER
*Acting Head, Department of Chemistry*
*Pfeiffer College*
*Misenheimer, North Carolina*

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# "Sciencing" in the Elementary School with Pendulums

**GEORGE C. SCHLENKER**
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Montclair, New Jersey

A basic, distinguishing aspect of all science teaching is laboratory work — activity which encourages investigation and discovery — which permits youngsters to practice "sciencing." Teachers, administrators, and writers of science materials are in general agreement on this point. However, the elementary classroom teacher who is desirous of conducting a science program, which is genuinely laboratory oriented, has considerable difficulty in finding specific teaching suggestions and materials for this approach.

In Montclair, we are slowly but systematically devising and testing activities and materials for elementary school science. These activities are designed to allow youngsters to discover relationships by observation, organization and interpretation of data, becoming familiar with the nature of measurement, acquiring skill in drawing reasonable conclusions, and making verifiable predictions from the data obtained.

These activities must be carefully selected so that they contribute to the understanding of basic scientific concepts and physical phenomena which are appropriate for the pupil at his present level of maturity. They should also be prepared in such a manner so that they can be developed and studied in greater depth in subsequent grades.

One such activity which has been extremely successful in the middle elementary grades involves a study of the motion of a pendulum.

The equipment required is simple, inexpensive, and easily obtained; *i.e.*, assorted fishing sinkers, string, dowel rods with holes drilled through which the string can be threaded, and a support stand which projects the pendulum beyond the edge of a student's desk. We have provided this material in sufficient classroom quantities so that groups of five or six pupils can work independently but under the teacher's general direction.

Teachers have introduced this topic — and aroused considerable enthusiasm — by telling their youngsters about Galileo's observations of the chandelier at the Cathedral of Pisa. Sometimes he observed it swinging in a wide arc; sometimes, in a narrow arc depending on the air currents in the building. The young Galileo, using his pulse beats to measure time intervals, made a discovery about the motions of this lamp.

The teachers have asked some simple questions: What do you think Galileo noticed? How do you think the number of times a pendulum swings back and forth in one minute can be changed?

The youngsters are quick to propose and anxious to test their suppositions about length, weight, and arc. At this time, they put their self-constructed pendulums into operation.

The type of data which they obtain from their experimenting, if recorded and organized carefully with the teacher's help, leads them to prompt verification or rejection of their proposals. One set of data obtained by sixth graders is shown in Charts I, II, and III.

Can the youngsters be helped to draw conclusions from this data? Our experience indicates that they can with little difficulty — especially if three or four other groups working independently have similar supporting data.

But this is only the beginning! In a classroom under the guidance of an imaginative teacher, the youngsters can be helped to discover many other interesting things; *i.e., The quotient obtained by dividing the number of swings per minute at length 20 inches by the number of swings per minute at length 40 inches is approximately 1.4. Similarly the quotient obtained by dividing the number of swings per minute at length 10 inches by the number at length 20 inches is also approximately 1.4!*

When collisions of moving and stationary pendulums of the same length are made to occur, the youngsters are amazed to see the transfer of motion! The motion of the pendulum as it moves from one end of its arc to the other can be described in words.

This activity certainly provides opportunity to gather and organize data, to make and confirm predictions, and to discover numerical and spatial relationships. But, it also does something more than this; it allows youngsters, using very simple and inexpensive equipment, to begin learnings which — in subsequent years — can be extended to develop concepts of acceleration and velocity, momentum, harmonic motion, as well as transformation and conservation of energy.

### CHART I

| Length of Pendulum (inches) | Swings of Pendulum Per Minute | | | Weight of Pendulum (ounces) |
|---|---|---|---|---|
| 50 | 54 | 54 | 53 | 4 |
| 40 | 60 | 59 | 60 | 4 |
| 30 | 69 | 69 | 69 | 4 |
| 20 | 83 | 84 | 82 | 4 |
| 10 | 119 | 117 | 116 | 4 |

### CHART II

| Length of Pendulum (inches) | Swings of Pendulum Per Minute | | | Weight of Pendulum (ounces) |
|---|---|---|---|---|
| 30 | 69 | 69 | 69 | 4 |
| 30 | 68 | 69 | 69 | 8 |
| 30 | 69 | 70 | 70 | 2 |
| 30 | 67 | 67 | 69 | 1 |

### CHART III

| Length of Pendulum (inches) | Swings of Pendulum Per Minute | | | Weight of Pendulum (ounces) | Length of Arc* (inches) |
|---|---|---|---|---|---|
| 40 | 60 | 60 | 59 | 4 | 4 |
| 40 | 59 | 59 | 60 | 4 | 6 |
| 40 | 60 | 58 | 60 | 4 | 8 |
| 40 | 58 | 59 | 59 | 4 | 10 |
| 40 | 59 | 57 | 58 | 4 | 12 |

* Youngsters determined this approximately by measuring the horizontal displacement when they started the pendulum swinging and then multiplying by two.

**HOWARD R. MUNSON**

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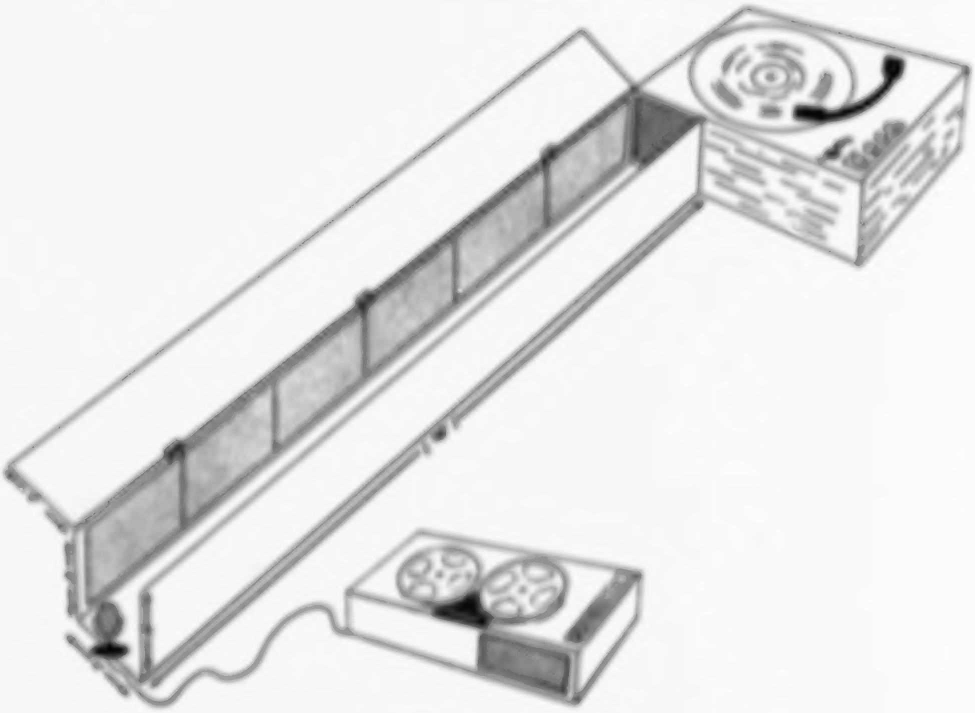
# SOUNDS In the Sixth Grade



A CLASS of sixth graders recently had a valuable experience in experimentation. While studying a unit on sound, they went to a nearby school building and observed a group of workmen applying acoustical tile to the ceiling. The children were intrigued by the tile and its soft structure. "Why do they use this, and what good is it?" "Can anything this soft be good building material?"

As the children probed with their questions, they discovered that the material applied to the ceiling is called acoustical tile, and that acoustics has something to do with sound control. They raised other questions: "Why is this material put on the ceiling? What effect does it have? What would happen if the whole room were lined with this material? Could other material be used in place of this soft, dotted, square board? Why don't we use this in our homes?"

The teacher encouraged her pupils to do individual reading; and they found information—some of which answered their questions, some which merely presented more questions. They discovered, for instance, that the acoustical properties of a room are related to the amount of sound-absorbing and sound-reflecting surfaces. They also learned that soft materials such as carpeting and drapery fabrics are regarded as sound-absorbing materials, whereas plaster, solid wood, concrete, and glass surfaces are sound-reflecting materials.

A class discussion led the children to the hypothesis that sound-absorbing materials can be used in school hallways and even in classrooms to minimize noise. However, a number of questions remained to be answered. Basically, the students were confused about the practice of using ceiling tile as a sound-absorbing surface.

The children wanted to test the sound-absorbing qualities of ceiling tiles and other materials. An experimental situation was designed by the students to compare various sound-absorbing materials. They needed a controlled sound—one that would be the same in each trial situation—and a means of recording the sound produced in each test to enable comparison. The materials and their arrangement, as used for the experiment, are shown in the figure.

A record player with a front-mounted speaker with a variable volume control was obtained. A wooden trough, or corridor, was constructed and fitted with a cover so as to form a rectangular tube 6 x 48 x 6 inches. The trough was then aligned with the phonograph speaker at one end and a tape recorder microphone at the other.

The pupils used the same portion of a record for each test situation with fixed sound control on both phonograph and tape recorder. A student made announcements into the microphone to explain the nature of each experimental situation. Several children conducted the tests while the others sat quietly and acted as judges to determine which acoustical treatment provided the best muffling (softening) of sound.

The pupils first recorded sound directed through an unlined trough. The wood surface represented the floors and walls of a school hallway without acoustical treatment. Then, the pupils lined the sides and floor of the corridor with soft material (flannel and velvet). The sound was again recorded through the trough. In the third situation, the lid was lined with pieces of acoustical tile to represent the ceiling of the room. The sound was recorded. Next, the ceiling and walls of the trough were lined with tile and tested. In the last experiment, the children constructed baffles of acoustical tile to prevent any direct passage of sound to follow from the phonograph speaker to the tape recorder microphone.

Hypotheses were made before conducting the tests, and after each method of muffling sound was tried, the results were compared. It was unanimously agreed that the trough lined with soft cloth, as in the second experiment, to represent carpeting and draperies provided a desirable sound control. The sound recorded when the corridor was lined with acoustical tile was judged to be nearly as well muffled as that which was recorded when the corridor was lined with cloth. Tile baffles provided the most effective sound control.

The children then applied the results to their environment. They decided that carpets and draperies are not practical for school hallways and classrooms and agreed that it would be impractical to construct a hallway with sound baffles. They concluded that a hallway lined with acoustical tile on the walls and ceiling would be the most effective and practical sound control method. Thus, the pupils arrived at conclusions as results of their scientific experiments with sound, applied these conclusions to their immediate environment, and supplemented their study of acoustics.

When the teacher asked how to improve the experiment, the students suggested finding a way to measure accurately the "amount" of sound reaching the end of the corridor. One student volunteered and interviewed a physics teacher, who was happy to help with a new experiment by demonstrating an oscilloscope. The interested children then formed a special group project and reported their results to the class.

In evaluating the experience, the pupils expressed their satisfaction in having "set up" an experiment from start to finish. Several students showed their desire to apply similar techniques when studying other science topics. Responded one child, "I felt like a scientist working on a new problem." Perhaps a spark which will eventually glow as a full flame was provided for at least one member of the class. That alone would make the experience worth the effort.

# *Off the Record*

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CHILDREN can find the study of sound to be one of the most fascinating areas of elementary science. Sound is a constant experience and is a most suitable area for simple experimentation and investigation. The equipment and material necessary for a classroom inquiry experience in the characteristics of sound are easily obtained.

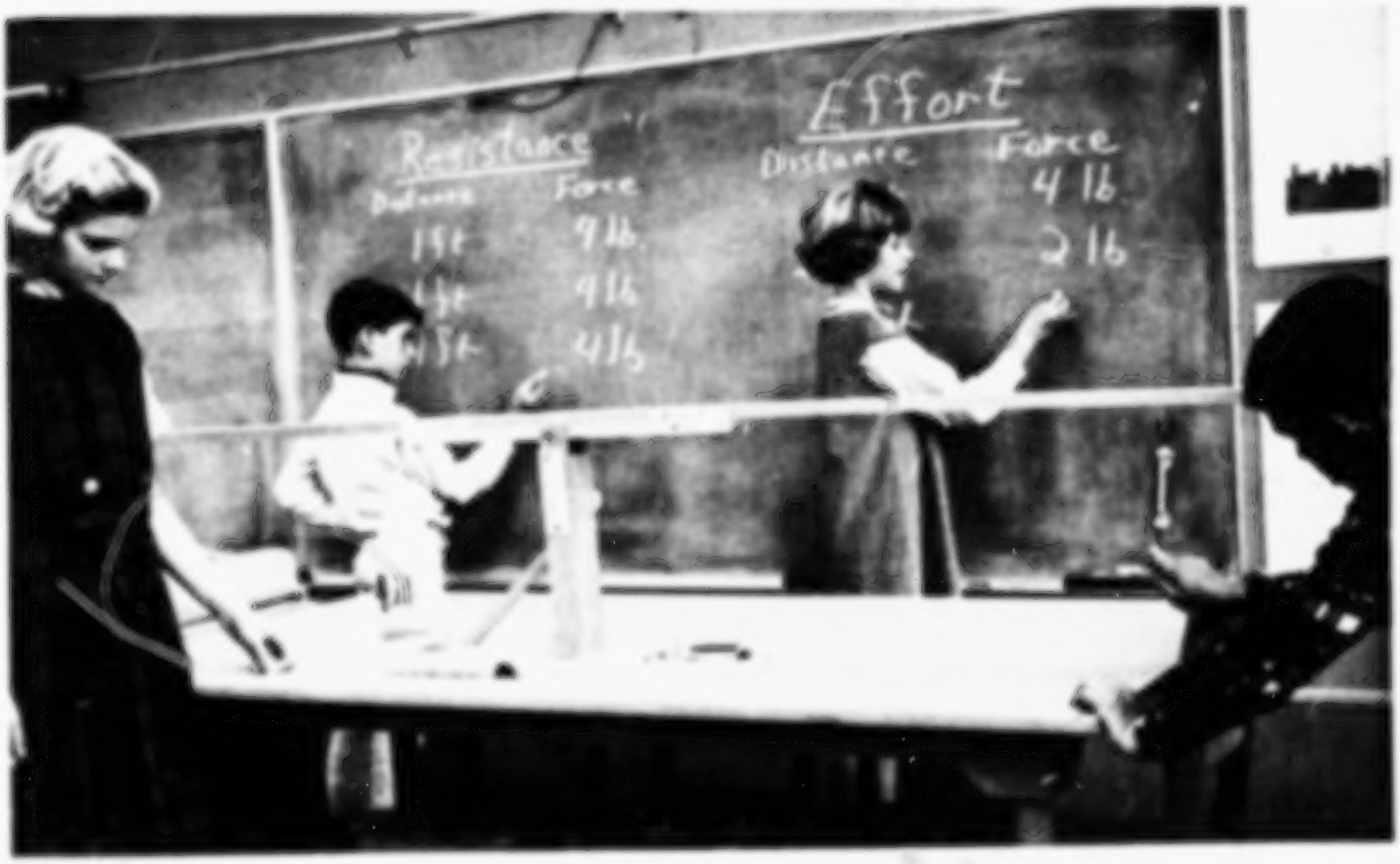
Locate an *old* 78 rpm phonograph record and a record player. Place the record on the turntable. The quietest part of the school day should be chosen for this experiment. As you start the turntable revolving, impress upon the children the necessity for silence. Instead of the phonograph needle in the instrument arm, try other objects that will vibrate in the record grooves and "play" the record.

Perhaps you could begin by selecting a child with long fingernails. In a very quiet classroom, sharp-eared children will be able to hear music played by a fingernail! This will seem mystifying to the children. A problem-solving situation has been created: How can a fingernail play a record?

Additional investigations can be conducted by testing any number of sharp-pointed objects—pins, tacks, needles, probes, razor blades, sheets of paper, and file cards. The class will discover that some objects will produce sounds better than others. Why? Is it the sharpness of the point? The way the object is held? Its length? Why doesn't the volume control affect the sound? Of what is a phonograph record made? Is sound stored in those little grooves in the record? The children will be able to investigate and answer most of these questions on their own.

More old records, even pieces of records, can be useful for further investigations. Have the children examine the record grooves with a hand lens. They will note that the grooves which have been traced in it by a vibrating object spiral from the outside edge in toward the center of the disk. (In the recording studio, a needle is made to vibrate by the sound waves of the music being played. These vibrations permanently etch a wavy pattern into the soft wax of the original recording.)

From this simple introduction, to the vibrating quality of sound and how it is recorded, the students can be encouraged to explore the characteristics of amplification and transmission of sound. Some pupils will have developed a curiosity about sound that they will wish to investigate, even on their own.



# Why Not Discover The Law of the Lever?

**JOHN V. SCHIPPERS**

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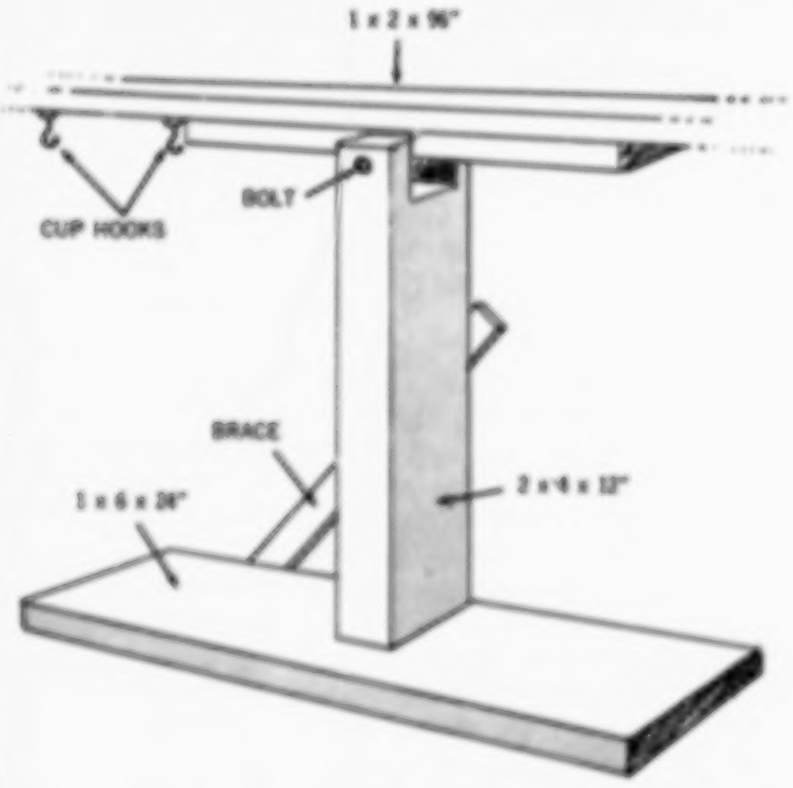
The use of a lever when teaching simple machines can reap great dividends in interest and knowledge by students discovering for themselves the mathematical relationships involved. Units on simple machines are found in many elementary school science programs in the primary as well as upper grade levels. A simple machine unit may well be placed in sixth grade to take advantage of the relationships between mathematics and science. The author has found that his sixth-grade students were challenged and stimulated by a lesson on the lever.

A unit on simple machines was introduced by presenting simple task-type problems to the class such as putting a nail into wood, breaking a piece of wood, and removing a nail from wood. This challenge was given to the class: "Suppose you were assigned the task of getting the nail out of this board, how would you proceed? You do not have any tools or other materials to use except what is here in the front of the room." No tools were provided but improvisations were permitted. After considerable difficulty, the children were allowed to use a claw hammer to pull the nails and a discussion was held on the reasons for the various types of attempts. The question was asked, "Did the hammer make you stronger?" It was established that something besides their bare hands was necessary for the task, even though each student's strength remained the same.

Words that were used by the students in discussion were written on the board; such as, work, machine, power, energy, force, pry, lever, friction, and resistance. Several questions were also asked and recorded. As new questions came up, they were added to the list. These words and questions were to be defined and answered as the study progressed.

Since the lever was frequently mentioned, it was decided to study it more thoroughly. Up to this time no



mention had been made of the reasons why a lever was helpful, only that it was. The teacher wanted the members of the class to discover for themselves that a lever increased force and the mathematical relationship of mechanical advantage.

### Building the Lever

At the next class meeting, a simple lever was introduced. The lever arm was constructed from an eight foot piece of 1 x 2-inch pine board. A hole was drilled through the mid-point of the lever arm support for the fulcrum nail. Cup hooks were spaced at one foot intervals along the board for hanging resistance weights on one side of the fulcrum and for pulling with the spring scale on the other side. The fulcrum stand was made from a piece of 2 x 4 x 12-inch board. This fulcrum stood on a horizontal base of wood, 1 x 6 x 24 inches. An extra piece of wood was nailed to the fulcrum and base for support.

Students were asked to show how the lever worked and to name the parts. Small label cards with fulcrum, resistance arm, and effort arm printed on them were then attached to the appropriate part of the lever. After discussing the parts of a lever, a mimeographed sheet containing simple diagrams of the lever was distributed to each class member. Each diagram showed the lever horizontally balanced, with four feet of the lever on one side of the fulcrum and four feet on the other side. As weights were placed on the lever, the students were to record this on their diagram along with the effort needed to balance it. The distances of both forces from the fulcrum were carefully indicated.

The reason for first balancing the empty lever was discussed by the class. It was decided that if accurate measurements were to be made, both sides should be equal at the start.

A 4-pound sack of sand was used as the resistance to be lifted. A spring scale was used to determine the effort needed to lift the resistance and a ruler was used to measure the length of the resistance and effort arms.

At this time, four students were asked to come forward and assist. A "mathematician" was chosen to do the computation requirements, a "recorder" to write the data on the chalk board, and two "technicians" were to operate the lever. Each student at his desk was to write in the resistance weight and distance and also include the effort and distance on his diagram.

The 4-pound bag of sand (resistance) was placed one foot from the fulcrum. The spring scales (effort) was placed one foot on the other side of the fulcrum. The "technicians" pulled on the spring scales until the lever was level (balanced) and read the amount of effort to the "recorder." This procedure was followed keeping the resistance at the same distance but moving the effort one foot further away each time until four effort-distance readings were taken.

Any answers to expected results of the length of the lever and effort required to lift the resistance were avoided by the teacher. After the first set of data was obtained, the pupils were encouraged to estimate what results would be found as the effort-distance was changed. It was hoped that the slower students would discover for themselves that the longer the lever, the less the effort and that the superior student would have insight enough to realize the mathematical relationship without first being told—the inductive approach rather than the deductive approach.

After the data were collected, a discussion was held concerning any relationships existing between the two sides of the lever. Almost immediately it was pointed out that one side of the lever did not change (the resistance side). This led to discussion of the effort side, the change here and *why*. During this part of the lesson, the generalization that the longer the effort arm the less the effort needed to move the resistance was brought out by the students.

### Mathematical Relationships

The more difficult concepts were to follow. Considerable time was spent on seeking mathematical relationships between one side of the lever and the other. Responses came spontaneously from the group as: "I can see on our first data reading the same figures, 4 pounds and one foot on the resistance side and 4 pounds one foot on the effort side." Then another: "Look at the last pair of readings, they are just the opposite, 4 pounds, one foot and one pound, 4 feet!" Many incorrect relationships were suggested and discarded as: "If you add both sides of the first and last readings, each side adds up to five." Since this did not hold true for any but the first and last readings, this idea was discarded. Subtraction proved equally frustrating. Then it came: "Multiply! If you multiply each side, they are the same!" Using our "mathematician" this relationship was shown to the class.

Testing this new found power, we attempted to predict what would be the result if we lengthened the lever. This led to the assignment for the next day. Since we had no way of lengthening the effort arm of the lever to prove our predictions, it was suggested that we change the distance from the fulcrum to the resistance weight. The resistance weight would remain the same but the length from the resistance to fulcrum would be changed from one foot to 2 feet. A second work sheet was distributed. This challenge was given to the class: "Using our newly discovered 'law of science,' try to determine mathematically what effort will be required to lift the resistance. At the next class meeting the results will be checked with the lever." Later, problems involving a change in the weight of the resistance were given.

Thus, a problem was presented which made use of the knowledge gained in class. At the next class period, students were chosen to collect data. These data were then compared with their mathematical predictions. In order to give each student an opportunity to work directly with the lever, different problems were set up. By changing the resistance's weights and lengths, new situations were created for the class to solve, first using their own theory and verifying with the lever. Pupils were encouraged to test their own predictions by using the lever during study periods.

Variations to the described lesson are easy to create. The use of pounds will involve multiplication of fractions. If the students are not adept at this, all readings could be given in ounces. Pre-determined "packaged" weights could also be used instead of spring scales. However, some instructional value would be lost by too much over-simplification.

Often errors of measurement will creep in to upset a perfect mathematical relationship. This may be distracting at first, but it presents an excellent opportunity to teach another concept of science—one experiment does not produce enough data for establishing a theory. Furthermore, there are many other factors which might affect the data. The students will be quick to point out some of these such as: friction at the fulcrum, inaccurate scales, inaccurate measurement of distances, resistance weight not centered over point of measurement, and human error.

Lessons such as this take several class periods to complete for it is time consuming to let class members experiment, collect data, analyze results, and form a generalization. Some may doubt the merit of spending such a length of time on something as simple as the lever. Experience has shown that such time is justified. The objective of the lesson was not to merely teach the "facts" of the lever because these facts can be taught by a diagram in a book and a few paragraphs of reading. True understanding and real concepts fail to materialize this way because interest and scientific thinking are not stimulated. The lever lends itself extremely well to the discovery method.

As a result of the above class work, the following conclusions are made:

1. Sixth-grade students can discover for themselves that a lever increases force.
2. Slower students were able to understand the general concept that the longer the effort arm, the less effort needed to lift the resistance.
3. Superior students were able to determine for themselves the mathematical relationship between the resistance side and the effort side of a lever and to use this knowledge to predict different situations.
4. A high level of interest and enthusiasm can be maintained by using the discovery approach with the lever.

* * *

# SCIENCE ACTIVITIES

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and
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**PROBLEM:**

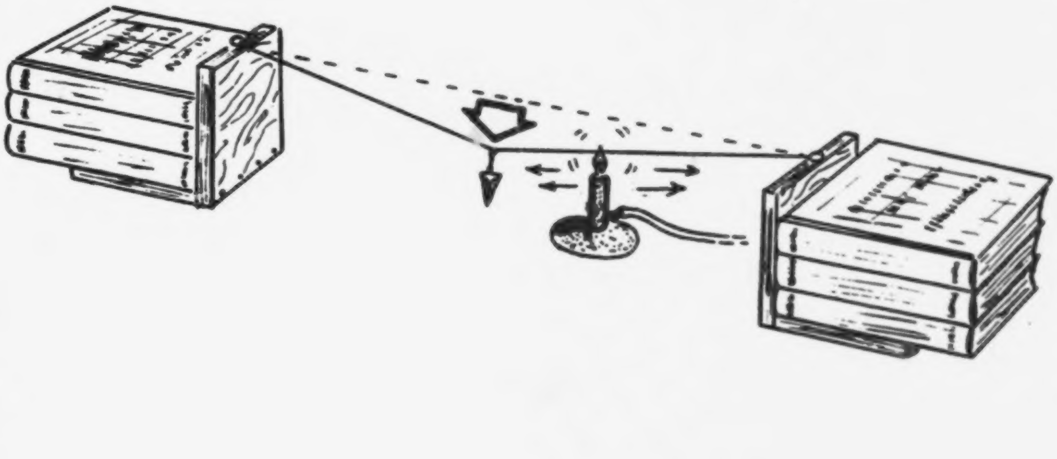
## Does Heat Cause Expansion of Metals?

**MATERIALS:**

Two supports, wire, string, a heavy bolt or steel nut, and a heat source.

**PROCEDURE:**

1. String the wire between two supports so that the wire is 12 to 18 inches above a table. (Make sure that the wire is drawn taut.)
2. Suspend a weight (nut or bolt) by string from the center of the wire. Measure the distance from the weight to the surface below.
3. Heat the wire. (Move your heat source along the wire.) Observe. What conclusions can you draw from this demonstration?



## For Primary Grades

# Quantitative Descriptions In Science

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SCIENCE in the primary grades should involve more than learning some of the properties or characteristics of things. Our environment—the universe—is better understood and becomes more meaningful to primary-grade students through measurement and quantitative descriptions. By using certain methods of measuring and collecting data, and then interpreting these data, pupils in the early grades can learn to predict quantitative events. The following two units have been designed to give children opportunities to use scientific procedures in developing quantitative descriptions of their environment.

### UNIT I.

#### Magnetism

The usual study of magnetism in the first or second grade includes a "will and will not" box. The children test many articles and classify them according to whether or not the magnet attracts them.

As an outgrowth of this activity, the teacher can develop the discussion, "How can we measure the strength of a magnet?" The children soon discover they can compare magnets by describing them as a "ten-thumbtack magnet" or a "five-paperclip magnet." This comparison will lead them to ask the question, "Can we tell the strength of a magnet by looking at it?" The development of guesses or hypotheses relating that shape, color, size, or weight may serve as a guide in predicting the strength of a magnet, which can be studied by having the children record and interpret data. The pupil's inquiries can produce the type of data shown in Figures 1-4. From such data, one classroom of children drew the following conclusions:

1. The *shape* of magnets does not help us to tell their strength.
2. The *color* of magnets does not help us to tell their strength.
3. The *size* of magnets does not help us to tell their strength.
4. The *weight* of magnets does not help us to tell their strength.

The collecting of original data as well as tabulating and analyzing of the data involved in this activity leads the children through a significant process to a scientifically sound conclusion: The strength of a magnet cannot be measured by its ap-

**Figure 1.**

SIZE OF MAGNETS

| Magnet | Size | Number Of Tacks |
|---|---|---|
| 1 | Largest | 21 |
| 2 | Large | 46 |
| 3 | Middle | 6 |
| 4 | Small | 19 |
| 5 | Smallest | 15 |

**Figure 2.**

SHAPE OF MAGNETS

| Magnet | Shape | Number Of Tacks |
|---|---|---|
| 1 | Horseshoe | 10 |
| 2 | Horseshoe | 8 |
| 3 | Bar | 4 |
| 4 | Bar | 8 |
| 5 | Bar | 47 |
| 6 | Bar | 16 |

**Figure 3.**

COLOR OF MAGNETS

| Magnet | Color | Number Of Tacks |
|---|---|---|
| 1 | Red and Silver | 7 |
| 2 | Black | 9 |
| 3 | Silver | 8 |
| 4 | Silver | 19 |
| 5 | Silver | 12 |
| 6 | Red and Silver | 15 |

**Figure 4.**

WEIGHT OF MAGNETS

| Magnet | Weight | Number Of Tacks |
|---|---|---|
| 1 | Heavy | 13 |
| 2 | Heavy | 7 |
| 3 | Middle | 8 |
| 4 | Middle | 19 |
| 5 | Light | 40 |
| 6 | Light | 8 |
| 7 | Light | 15 |

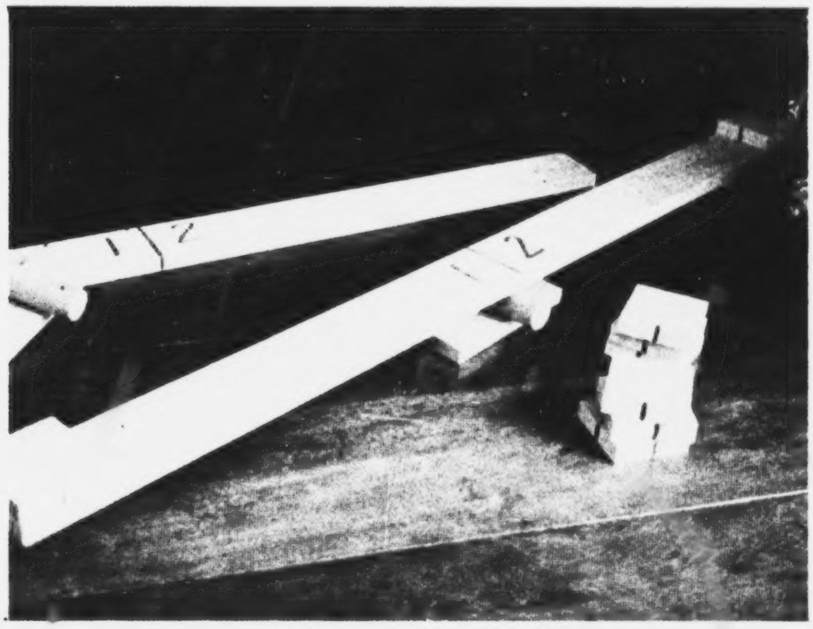
Figure 5.

pearance. The entire process from the first statement of the problem to the final conclusion is well within the thinking abilities of the primary pupil and is much more challenging than the identification of objects attracted. As an outgrowth of this unit, electromagnetism may be investigated, which will produce some positive results to similar investigations.

## UNIT II.

### Beam Balance

Construct a beam balance as shown in Figure 5. On a strip of wood, mark equally measured distances from the center. Then obtain several wooden blocks of equal weight to use for the experiments.

The study of balance can be initiated in the lower grades by raising the question: "How can I keep this board balanced?" Discussion will lead to the use of words meaningful to the unit—balance, center support, balance board—and also the use of equivalent weights.

The children can be encouraged to try different arrangements to produce a balance. As they attempt each pattern, have them state what they intend to do and what they expect to occur—their hypothesis or guess. The results of every test should be recorded (whether successful or not!). Every attempt (experiment) is important for complete understanding.

As the collection of "successes" begins to build up, children can begin tabulating the data. The teacher can ask, "How can we measure this arrangement so that we can describe it better?" She can encourage the students to record the data in chart form.

The teacher plays an important role in guiding the children into making worthwhile measurements and recording these measurements on meaningful tables. At times, it may be necessary for her to encourage the rearrangement of the data in order that the children will more readily see the relationships.

All attempts should be recorded on the first chart, but after refining the data only the successes need be used. Identify attempts by recording the number of units of distance away from the center of the board where the stacks of blocks are placed and the number of blocks placed on each side. Figure 6 shows data gathered from a beam balance arrangement like that shown in Figure 5.

Figure 6.

BEAM BALANCE EXPERIMENT

| | SIDE 1 OF BOARD | | SIDE 2 OF BOARD | | |
|---|---|---|---|---|---|
| **Experimenter** | **Distance In Units** | **Number Of Blocks** | **Distance In Units** | **Number Of Blocks** | **Results** |
| Lee | 1 | 1 | 1 | 1 | Balanced |
| Elliot | 1 | 1 | 1 | 2 | Not Balanced |
| Diane | 1 | 2 | 1 | 2 | Balanced |
| Bob | 1 | 3 | 1 | 1 | Not Balanced |

From these data, the children can generalize that it is necessary to have equivalent situations on each side (just as in a conditional equation in arithmetic, the two sides must be equivalent):

1. If we have more blocks on Side 2, we will need more distance units on Side 1.
2. When the number of blocks on Side 1 is one and the units on Sides 1 and 2 are equal, then the number of blocks on Side 2 is one.

If the generalizations and interpretations of the data are carefully made they will have predictive value. The children, therefore, should be encouraged to use these generalizations to make predictions.

### Conclusions

The purpose of each of these teaching units is to help children discover relationships about the phenomena for which they have collected data. In each lesson, the children have been encouraged to develop guesses (hypotheses) about what they expect to happen; to establish a situation (experiment) to test their guesses; and, as a result of these guesses and the ensuing situations, to collect original data and classify them into tables. After studying and understanding the material in the tables, the children can form generalizations with predictive value. Classroom activities such as these also give children practice in the use of scientific procedures by involving the quantitative measurement of events and the interpretation of data.

# The BINARY SYSTEM And COMPUTERS

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Why teach other systems of numeration? Certainly, most students will not have a direct application of this knowledge in their daily lives. However, the process of constructing a new system of numeration is a valuable experience for a student in the upper elementary grades. He will be able to see the difference between a number (an abstract idea) and a numeral (a way of symbolizing the number idea). He will realize that the numeral 100 has many meanings depending on the base being used. The student may truly understand the idea of place value for the first time as he sees its role in other systems of numeration.

In the commonly used base-ten, or decimal system, it is only possible to count to nine using single-digit numerals. No single-digit numeral is available to write a numeral for ten. Therefore, the ten's are grouped with the numeral 10 indicating one group of ten. Since the student is grouping by ten, each *place* is a power of ten; for example, 100 represents one group of 10 times 10 or $10^2$, 1000 represents one group of 10 times 10 times 10 or $10^3$, etc.

In the base-five system, the digits 0, 1, 2, 3, and 4 are used. In order to symbolize the idea of five, a grouping is necessary with the numeral 10 indicating a group of five. In the base-two or binary system, the only digits used are 0 and 1. All numbers are expressed by these two digits. Since the grouping is by twos, 10 would symbolize a group of two. The places must express powers of two; for example, 100 (read one-zero-zero or four) represents one group of two times two or two to the second power; 1000 represents one group of two times two times two or two to the third power.

Although the idea of base-two is very old, its present use in electronic computers makes an understanding of this base very timely. Any number in the binary system can be easily represented with the use of electricity—one of the symbols can be represented by the absence of current and the other by the presence of current.

One problem encountered in working with other bases is a problem similar to one encountered in learning a foreign language. The student tends to translate continuously to the more familiar language in order to think in his native "base." By constructing a simple computer, it is possible for the student to compute mentally and then read his result in base-two without ever having to translate to base-ten. He does not have the temptation to use symbols that are not available within this base. All he has available is a series of lights which can be turned on or off.

The student can build and use a simple computer from some flashlight cells, bulbs, index cards, cardboard, tape, and several five-inch pieces of wire. (See Figure 1.)

*Procedure:*

Remove the insulation from both ends of each piece of wire and twist one end around the base of a bulb. Bend the wire to the contour of the dry cell with the bottom of the bulb resting firmly on the top of the cell. Tape the other end of the wire to the bottom of the cell. Now, the light bulb should be on. Then make switches from the index cards by cutting strips about ¾ inch by 2½ inches with a triangular gap on one side as shown in Figure 1. Make two folds in each strip and tape them to the cells in such a way that the strip can turn the bulb off by preventing it from touching the cell. The index-card strip works as a

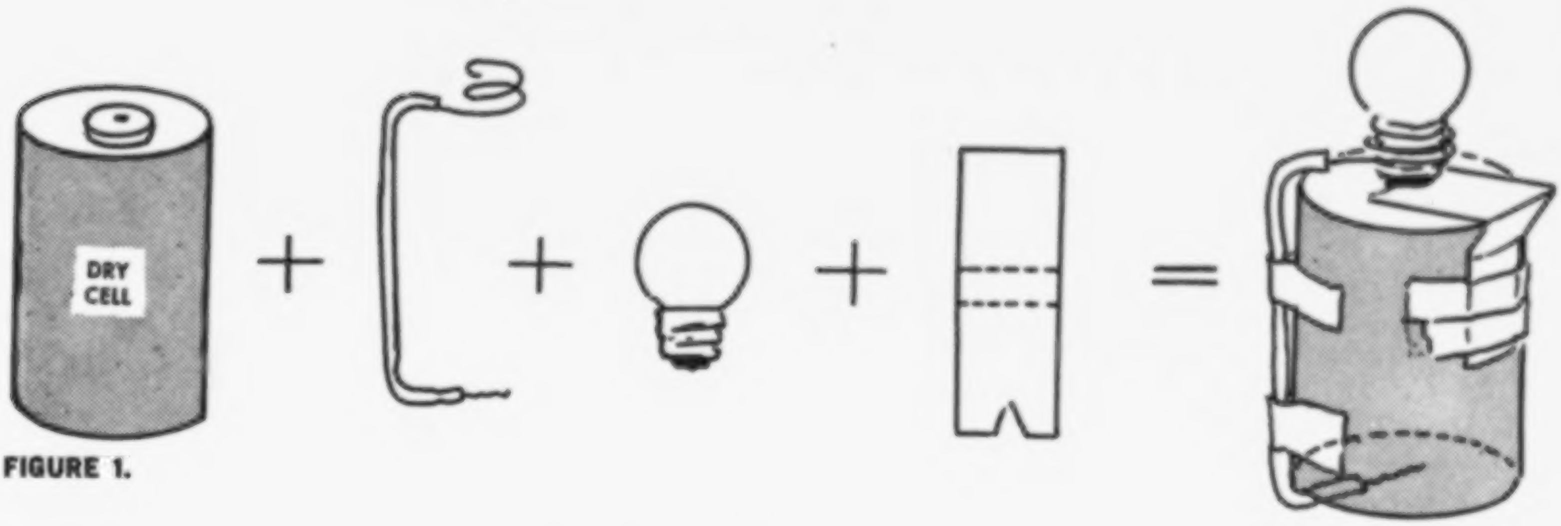


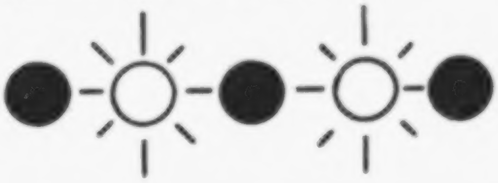
FIGURE 1.

switch by flicking it back and forth with the thumb. (When the bulb is off, it has no value.)

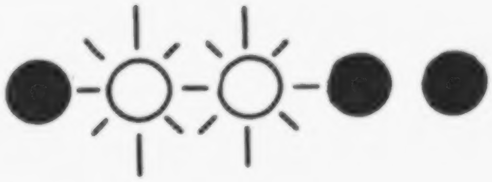
The student can follow the above procedure with as many cells as he likes. If he tapes cardboard around a group of five cells, he can add numbers up to 31, six cells to 63, seven cells to 127, and so on. (See Figure 2.)

In doing the computation, he can use one or more rows of cells. Using three rows, he can represent the two addends and their sum on separate rows, retaining a complete record of the operation. Using the one row computer, he must keep track of the operation mentally or on paper.

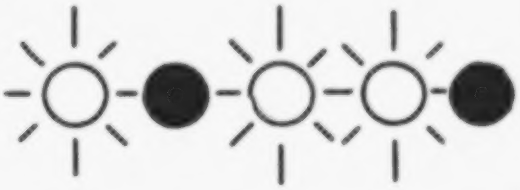
Let us assume that he wants to add twelve to ten. First he must know that the symbol for ten in the binary system is written as 1010 or represented on the computer as:



and that the binary system symbol for twelve is represented as 1100 or as:



The sum of 1010 + 1100 is 10110 (22). It is represented on the computer as:



How was the computer operated to arrive at the above sum? Can you add 12 to 20 with a five-cell computer? Try to compute 11 plus 13.

### Related Readings

1. Irving Adler. *Thinking Machines.* $4. John Day Company, Inc., 121 Sixth Ave., New York City 10013. 1961.
2. Arthur Jones. *New Ways in Math.* $2.95. Prentice-Hall, Inc., Englewood Cliffs, N. J. 1962.
3. Alan Vorwald and Frank Clark. *Computers: From Sand Table to Electronic Brain.* $3.50. Whittlesey House, 330 West 42nd St., New York City 10036. 1961.

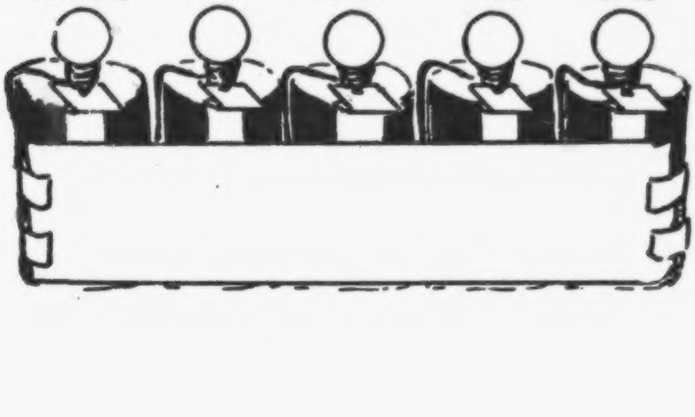


FIGURE 2.

# SECTION 5 PROPOSED STRATEGIES FOR TODAY AND TOMORROW

## Introduction

In recent years, nation-wide science curriculum studies have appeared on the scene. The trend for experimental curriculum projects began with attention being given by scientists and science educators to the development of new high school science courses in physics, biology, and chemistry. After these secondary-school studies were launched, curriculum projects for elementary-school science emerged. Many of these experimental studies have been given financial support by the National Science Foundation.

The science curriculum projects for the elementary school are examinations of the "what" and the "how" of science teaching. Emphases are placed upon the structure of the disciplines and the processes of science. In other words, these studies propose approaches for making science teaching in the elementary school more "sciencelike."

Most elementary educators are undoubtedly aware of the fact that science curriculum projects are in progress. However, unless there is direct involvement in one of the studies, a classroom teacher may not have had the opportunity to assess the implications of the studies for his teaching. Various issues of *Science and Children* have contained reports of some of the recent experimental studies, some of which are financed by the National Science Foundation. The section begins with a reprinted editorial from the journal which should help the reader to develop a perspective for his consideration of the following reported studies. The closing article presents a point of view regarding the effect which national-level curriculum projects can have on science in the elementary school.

Certainly, an elementary educator will wish to appraise the pertinency of the experimental studies in relation to curriculum planning and teaching procedures. In examining the purposes of these studies, some criteria might be identified for the evaluation of present programs of science in the elementary school. The accounts of the projects might also suggest some clues for the planning of specific teaching-learning experiences. Perhaps the inclusion of these reports of experimental studies will lead the reader to seek fuller accounts of the projects, with the result that discriminating use of the proposed approaches may offer possible new strategies for the teaching and learning of science in the elementary school.

## SECTION 5 PROPOSED STRATEGIES FOR TODAY AND TOMORROW

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# Editorial . . .

The recent involvement of scientists in developing science curricula for our elementary and secondary schools has rendered many outstanding and revolutionary contributions to science education. They have helped in identifying the structures of the disciplines of science, in clarifying the processes they employ, and in demonstrating their modes of inquiry.

## More "Sciencelike" Science Teaching

As a result, many curriculum projects have emerged throughout the country, all of which are directed toward the improvement of science instruction. Most of these projects are constructed around significant themes, discovery methods, and a spirit of inquiry. These projects might be described as attempts to make science teaching more sciencelike.

Many school districts are becoming engaged in pilot programs and experimental projects in an effort to implement and evaluate the products and potentials of each of these efforts.

But, as the materials of each project are taken into the classroom, what becomes the teacher's role in this scientific process of making science teaching more sciencelike? What is the unique place of these materials in the fleeting and sensitive personal confrontation between teacher and pupil in the teaching-learning situation?

The scientist is a creative being, so too, must the teacher be the innovator, the intuitivist, the perceiver. As a scientist works to define a problem clearly, the teacher, likewise, must seek a well identified behavioral goal. Much as the scientist searches for relationships and gathers substantiational data, so too, the teacher seeks information about the interaction between pupil and content in the learning act. As the scientist experiments, so must the teacher try new methods and materials, selecting some and discarding others, evaluating teaching outcomes, and gathering evidence of pupil growth.

If materials for science education being produced today do not enhance a scientific basis for the teaching act, then they would surely fall short of making science teaching sciencelike. To produce anything less, would cast the teacher in the role of a mere technician—carrying out the innovations of others, gathering data to substantiate someone else's theory or replicating some foreign experimental design.

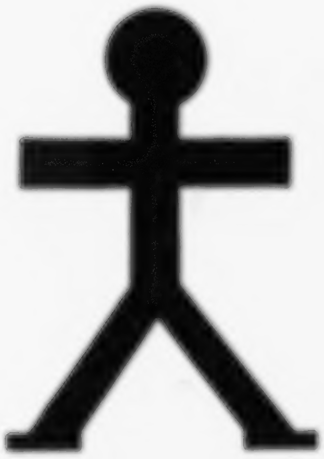
A paradox facing science educators has always been that *learning* is an individual endeavor while *education* is a social phenomenon. This dictates that structures and processes, continuity and sequence must ultimately be considered in terms of their psychological and emotional significance to the learner himself. But the link between the learning endeavor and the teaching act may best be forged by utilizing a more scientific method of inquiry. Thus, available materials must be scrutinized to find their proper place in the classroom. Just as any new scientific theory is advanced, a test of its durability is its ability to stand up under the investigation of other scientists. Likewise, as new curriculum materials and programs are made available, they too, must be tried, tested, and evaluated. To accept them without question and implement them with indiscretion, would be the antithesis of our major objective. To expect their complete success, would display arrogance in an arena of humility.

Perhaps some inquiries should be explored when considering the material made available from national curriculum projects. Inquiries should be made in terms of our present thinking about the disciplines of science, about teaching processes, and about current learning theories. Such interrogation should be developed and conducted locally, however, some suggested questions might be:

1. Are the goals of the project clearly defined? How do they coincide with the goals established for the individual child, for the school system?
2. Does it provide for broad evaluation in terms of their purported goals? How will evaluation data be gathered?
3. Are there sufficient, diverse, and valid materials for student use available on a variety of levels of sophistication? Which materials already available locally will fit into these goals?
4. How will this learning opportunity contribute to and enhance the unique qualities of every student? Does it account for variability in learning? How does it accommodate diverse cognitive styles, socio-economic levels, and ethnic backgrounds?
5. Will there be opportunity for continuity, sequence, and integration so as to finish a reinforcing, developmental, and relational type of learning experience?
6. Is the proposal truly better than what is being done now? How will such progress be measured?
7. Is the material flexible enough so that it may be implemented in part or blended with existing sound practices?
8. Does it capture the essence of science, leading to the structure of disciplines employing experimental and scholarly methods?
9. Are teachers well equipped and experienced in the methods of science, so as to inspire, demonstrate, elicit, and recognize such behaviors in children?

More inquiries of this type, of course, should be developed. But if these are thoroughly and thoughtfully explored, the implementation of current materials from national science curriculum projects can serve well to make science teaching more sciencelike.

ARTHUR L. COSTA
*Sacramento County, California*



# Meet Mr. O

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Allow me to introduce Mr. O. Mr. O is an artificial observer. He knows where every object is at all times, but he always describes the location of everything relative to himself. He is the most important thing in the world. He does not wonder why; why events happen, or why objects appear the way they do. He "reports" in his very egocentric way only what can be observed and what happens.

Is Mr. O like a real person? No, of course not. Mr. O is an invention of the human mind. His characteristics are assigned to him for pedagogical reasons and not to make him resemble a person. In his "reports" he summarizes the knowledge of the person who uses the Mr. O concept, and he is not confined by perceptual limitations of his own.

If a Mr. O on a table is asked, "Where are you?" he can only answer, "I am right here," perhaps while pointing to himself. If he were asked, "Where is the table?" he would say, "Underneath my feet." For the pupils in a class, of course, Mr. O is on the table. Such a point of view, however, subordinates Mr. O to the table. For Mr. O, he himself is the central reference point, and the way he faces defines the reference directions. Since he accepts no external reference object, he has no way to describe where he is other than by pointing at himself and answering, "Right here."

**The experiments in this article were carried out by the author at the Berkwood School, Berkeley, California, through the cooperation of the Director, Betty Halpern. Financial support for the project was provided by the National Science Foundation, Washington, D. C.**

As was pointed out above, Mr. O is an artificial observer. His characteristics are unlike common sense. Yet three examples will show that everyone's common sense outlook involves the use of the Mr. O concept in an unconscious way.[1]

*Example 1.* Mother drives her daughter to school. The girl starts to climb into the back seat. "Don't move around so much. Sit still," mother says. The daughter obeys. That satisfies mother. But is daughter really not moving? That depends. For a Mr. O in the car, she is indeed sitting still. For a Mr. O on the sidewalk, however, the car, the mother, and daughter are moving past at perhaps a rate of 30 mph. Mother automatically uses both of these Mr. O's: one inside the car when she thinks about her daughter's behavior; one on the sidewalk when she thinks about the car as a whole.

*Example 2.* In a bus, the situation is still more interesting. As the bus starts suddenly, the passengers seem to fall backwards. Do they really fall backwards? Not for a Mr. O on the road; for him, they are

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[1] Benjamin Lee Whorf. *Language, Thought, and Reality.* John Wiley and Sons, Inc., New York City. 1956.

*The students, under the direction of the author, work with their own Mr. O's to get an understanding of the relationships of objects in a system.*

moving forward, but more slowly than the bus. For a Mr. O on the bus, of course, they do move backwards. Who is right?

*Example 3.* In astronomy, everyone learns that the earth rotates on its axis and moves around the sun. Is this true? For an observer on the sun, it is. But for an observer on the earth, the earth does not move at all; it is fixed beneath his feet. Instead, the sun and moon move around the earth and show certain seasonal variations. Which idea is right?

Once the observer fixed on the earth was the only one considered consciously. Nowadays, man's thinking is more nimble, and he can conceive of the different observers that have been mentioned and many more. Each Mr. O is right for himself, from his point of view. The question, "What is *really* happening?" has no scientific meaning any more. Instead, the scientific mind thinks about a phenomenon from several points of view and then chooses the one that permits the simplest description and that leads to the best understanding. For this reason, everyone thinks about the solar system like an observer on the sun. Which observer to choose for studying the passengers on the bus is less clear.

Now, motion and change are fundamental aspects of natural phenomena. To communicate a clear and sensible description of motion and change, one must specify the imaginary observer who would make that same description. It is especially important that one be aware when one is using two or more different observers for different details of the same process or change, as mother was doing in the first example.

In brief, the concept of motion of an object is not an absolute one. It is meaningful only when referred to a certain environment, often called a reference frame, which may be selected consciously or unconsciously. In the common sense view, motion is usually seen in terms of the immediate environment of the object of interest. Thus, the daughter is seen relative to the automobile interior, the automobile relative to the road, the road relative to the surrounding countryside, the countryside relative to the whole earth, the earth relative to the sun, the sun relative to our galaxy, and our galaxy relative to the system of galaxies called the universe. Each environment can in turn become the object of study in a still larger environment. And with each environment that plays the role of a reference frame, a Mr. O can be associated so as to represent this function in our study.

## Motion and Change Studies

Because motion and change are so fundamental to science, the author has developed a series of lessons on that subject. One teaching objective was to make the children conscious of the reference frames they use. A second objective was to teach the children to use a particular reference frame more broadly than is done according to common sense. For example, it is contrary to common sense to consider the behavior of the road relative to the automobile. Yet scientific understanding often requires thinking that transcends the ordinary patterns. Puppet Mr. O's served as concrete representations of abstract reference frames. The remainder of this article contains a sketch of procedures that have been used by the author with some success to teach elementary school children aspects of the relativity of position and motion.

The principal intellectual effort required of the children was the mental isolation of the experimental objects under study from the remainder of their environment. When a Mr. O was introduced, the positional relation between the objects and him had to be recognized. Often the cues inherent in the environment, such as the walls of the room, the trees, the desk, the edge of a paper, served as unconscious reference frames and interfered with the children's efforts to take Mr. O's point of view. At the beginning, indeed, the children treated Mr. O as an object (moving or standing still) relative to some conventional reference frame. With a little practice, however, the children between six and ten years of age learned to think in terms of Mr. O.

## The Lessons

**Lesson 1.** *Misunderstandings that arise when the reference frame is not specified.* The teacher tells the story of Joe, his wagon, and his dog Spots who, when he is hitched to it, can pull Joe in the wagon.

Joe likes his wagon very much. When he rides in it, he thinks just of Spots, the wagon, and himself. Joe goes for a ride one day in his wagon. Spots pulls them into a forest, and they get lost. Mother looks for Joe, and she calls him when she cannot find him, "Joe, Joe. Where are you?" Joe answers, "Here I am, in my wagon!" Was that right? Yes, it was exactly right. His mother replies, "You stay where you are. I'm coming after you. Don't move." Joe, who is a good boy, stays right where he is in the wagon, but Spots, who cannot understand words, keeps on walking. Did Joe obey his mother? Yes, he did. He did not move at all. After a while his mother calls again, "Joe, where are you? I told you to stay where you were!" And Joe answers, "I'm right here in my wagon where I was before . . . !" Eventually, the wagon hits a rock and tips over. Joe's daydream is shattered. He hears his mother calling him again, "Joe, where are you?" This time Joe answers, "I am next to the largest tree in the forest," and his mother soon finds him.

Children, who are often very literal, understand and enjoy the misunderstanding between Joe and his mother.

**Lesson 2.** *Explicit introduction of Mr. O.* A large wooden block and a wagon were used for this lesson. The teacher called the children's attention to the block standing on a desk and asked them to think just about the block—not about the desk, or the walls, or the floor. The pupils were reminded of this several times subsequently. In answer to questions, the children replied that the block could not move unless someone pushed it because it does not have legs or muscles. When the teacher waved the block in the air, the children variously commented that it was moving or being moved. Next, one child was asked to sit in the wagon and hold the block tightly on her knees. The teacher pulled the wagon across the room. Was the block moving now, or was it staying in the same place? The children in the class thought it had moved, while the child in the wagon insisted that she had held it still. Who was right? Everybody was right! And to help the class discuss the problem, the teacher introduced a puppet observer, Mr. O, with the properties described at the beginning of this article.

One special characteristic of Mr. O can now be explained. Mr. O does not wonder how or why objects look the way they do, nor is he concerned with what causes events to happen. He is interested only in what happens and the appearance and position of objects. This feature is introduced because some children tend to combine in their thinking the activity that causes the motion with the motion itself. To help them

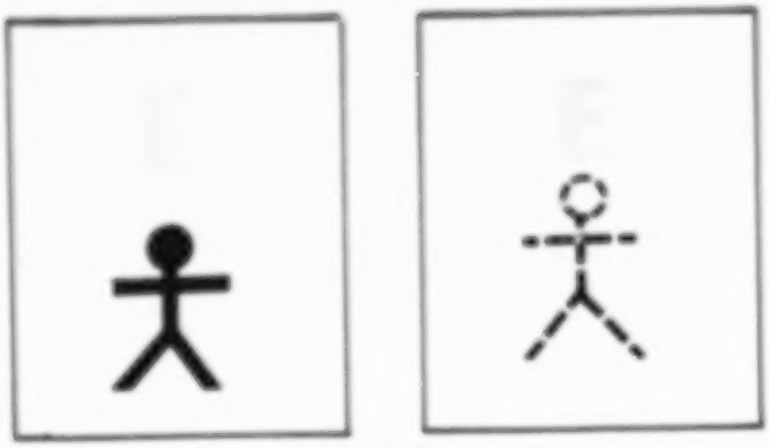

FIGURE 1.

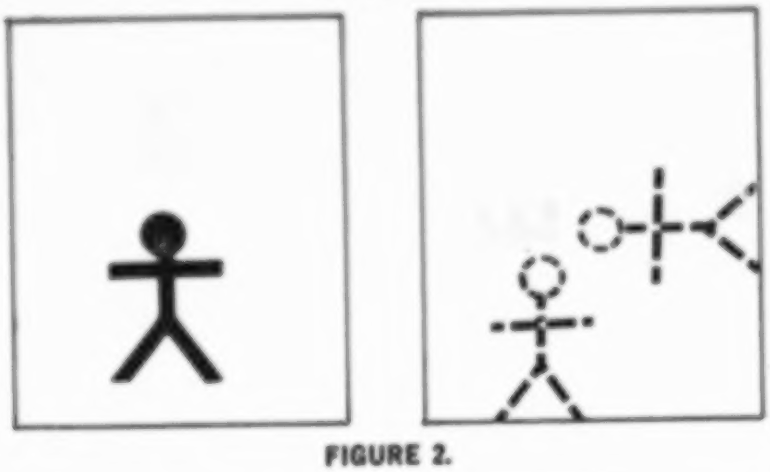

FIGURE 2.

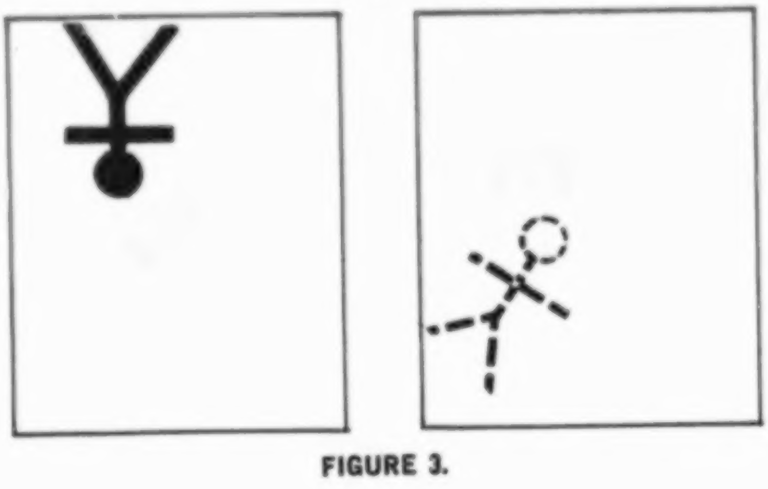

FIGURE 3.

separate these two aspects of a process, Mr. O notices only the motion, the change in position. At this stage, the rules for using Mr. O are like the rules of a game that have to be learned. Eventually, the children will discover that the game helps in dealing with the reality.

The teacher gave a Mr. O to each child. The experiment with the block was repeated and discussed in terms of the observations of Mr. O. The Mr. O on the wagon considered the block stationary, while the Mr. O's on the desks observed that the block moved from one place to another. Who was right? Each one was right for himself. Mr. O served as a concrete representation of a reference frame.

**Lesson 3.** *Extension of use of Mr. O; viewing a process from two different reference frames.* The demonstration in lesson two was repeated in a modified way. Now one block (block A) was placed on a desk and a second block (block B) was loaded onto a large toy truck. One Mr. O rode on the truck, and each child had a Mr. O on his desk. The teacher pushed the truck along the desk. The Mr. O's were to observe only the two blocks—not the truck, not the desks, not the children, not the room. What do they report? The Mr. O's on the desk reported, according to the children, that block A stayed in the same place but that block B moved. The Mr. O on the truck reported that block B stayed in the same place but that block A moved, or seemed to move. This accomplishment on the part of the children revealed their ability to participate in a game even if the rules appeared to be strange. Some children interjected, "But *really*, block A stayed in the same place!" To this comment the teacher replied that the children were favoring the Mr. O on the desk whose report was more real to them. The children should not play favorites with the different Mr. O's.

**Lesson 4.** *Mental separation of objects from environment. The term "system" is used to denote the object or group of objects under observation by Mr. O. Temporarily, he disregards all other objects.* Duplicate cutouts of a colored paper "E" were placed on two flannel boards. A small paper Mr. O was placed near each one in such a way that each saw his system in the same way that the other saw his (Figure 1). The Mr. O's were observing only the system specified, *i.e.*, the paper "E"—not the flannel board, not the room, etc. Now the teacher picked up one shape and replaced it in a different orientation. The other flannel board remained as the unchanged model (Figure 2). Do the two Mr. O's see their systems in the same way now? No! How can we place the second Mr. O so he will see his system in the same way? Several children were given paper Mr. O's in order to try their

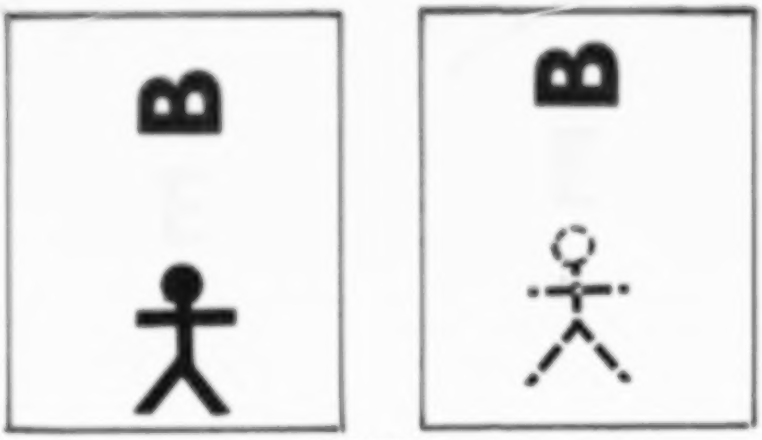

FIGURE 4.

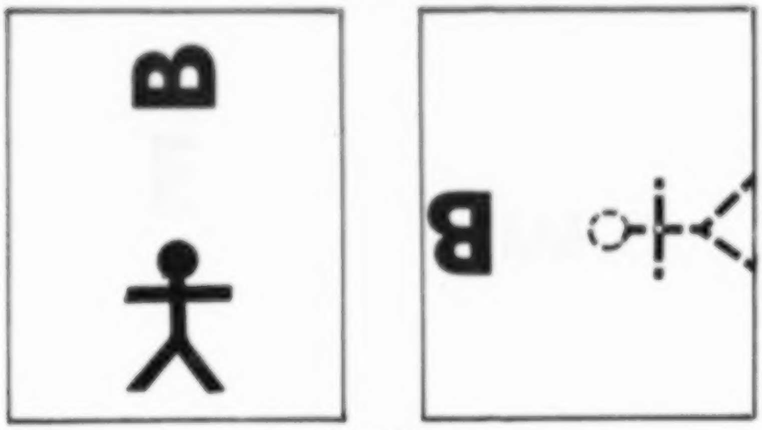

FIGURE 5.

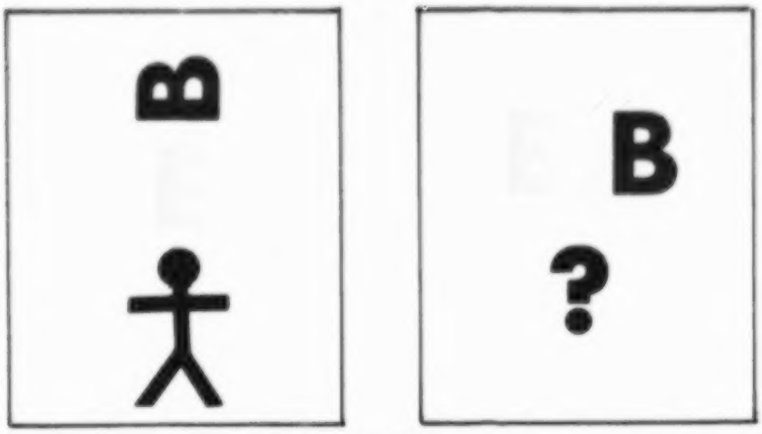

FIGURE 6.

ideas of his placement on the flannel board. After a while, this flannel board was picked up by the teacher and held near the model board. Now the model Mr. O and one of the children's trial Mr. O's were lined up so their points of view could be compared easily. It was simple to determine whether the systems were seen in the same way. If they were not, the incorrect trial Mr. O was removed. Eventually, only one trial Mr. O was left on the board. This activity was repeated with different children participants and other placings of the letter (Figure 3). The children also worked at their desks with puppet Mr. O's observing a block or a toy house "in the same way" as a model set up by the teacher or another pupil. Further drill was provided by worksheet exercises in which children drew a Mr. O near a picture of the system so he observed it in the same way as the model. Some children discovered that with certain systems, called symmetrical by adults, it is possible to have two or more distinct Mr. O's all of whom see the system in the same way.

**Lesson 5.** *Relation of objects in the system to each other.* This lesson began in the same way as Lesson 4, but two colored shapes, the letter "B" and the letter "E", were used on each flannel board instead of one. The situations shown in Figures 4 to 6 were set up successively with the children supplying the Mr. O in each case. In the last example shown, there were several trials that were always criticized by other children and eliminated. Finally, one girl exclaimed that the task of finding the correct position for Mr. O was impossible. The system really looked different. It had been changed. In later activities, the problem was turned around. The children were given two paper shapes that looked alike. They were asked to operate on one so it would then be impossible to find a Mr. O who saw it in the same way as a second Mr. O saw the other. A few children were baffled, but many tore or wrinkled the one shape so that it, indeed, would look different no matter how Mr. O was placed.

## Summary

Variations of these five lessons involving somewhat different activities were alternated. The children's ability to analyze the motion of objects was improved by the experience of the later work on isolating objects and systems in their thinking. One entertaining family activity that supports this teaching program uses a Mr. O who rides behind the windshield of the car. How does he describe the motion of various objects, such as homes, cars, etc.?

A most important outcome of this teaching program was to lead children to consider a process or phenomenon from several points of view, an objective that is valid also outside the science program. This article, however, has been confined to physical situations.

The sequence of lessons that has been described was part of a larger teaching experiment. In class periods that preceded the lessons on Mr. O, the children learned to describe a group of objects that attracts their current interest as a "system" of objects to be distinguished from the environment or background. They also recognized that objects do not usually exist in isolation, but that they affect or influence one another. In subsequent class periods, the pupils explored some ways objects influence one another and how this determines what happens to the arrangement of the objects in the system. One of these lessons has been described in the article "Discovery or Invention."[2]

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[2] J. Myron Atkin and Robert Karplus. "Discovery or Invention." *The Science Teacher,* 29:45-51. September 1962.

# Science for the First Grade

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Yes! Elementary school pupils are entirely capable of mastering more sophisticated scientific facts than we have taught them in the past. However, merely "pushing-down" junior high school general science into the elementary school, high school science down into the junior high school, etc., is not the solution to the plaguesome question, "What science should we teach in elementary school?"

Science as practiced by the professional scientist is simply solving the puzzles which confront him. This should not be construed to imply that others in our society do not also attempt to solve puzzling situations, but science appears to be the best vehicle to present this type of teaching in the elementary school.

The famous French mathematician and philosopher, Henri Poincare (1) * in reference to the motives of science related, "The scientist does not study nature because it is useful; he studies it because he delights in it, and he delights in it because it is beautiful. Of course, I do not here speak of that beauty which strikes the senses . . . the beauty of qualities and appearances; not that I undervalue such beauty, far from it, but it has nothing to do with science; I mean that profounder beauty which comes from the harmonious order of parts and which a pure intelligence can grasp."

If science is to be taught as a duality, viz., *process* and *product*, if pupils are to learn not only the facts of the discipline but also its "structural features," (2) then perhaps the entire endeavor of science should be analyzed and presented to the pupils in a sequence adapted to their developmental level. Pupils will then be led through an ordered series of activities in which they will be truly practicing the skills used in the scientific endeavor, starting with the most elementary skills and progressing to the more complex.

The Elementary School Science Project of Utah State University, Logan, Utah, has made an attempt to teach the duality of science commencing with the first grade. This has been an interdepartmental approach[1] involving principal investigators from the departments of physics, bacteriology, and mathematics, aided by an assistant director from science education and first-grade teacher consultants from the local public schools. Consultants from the psychology department were engaged to provide much needed information concerning child growth development and principles of learning. The stated objectives of this team include the following:

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* See references.

(a) To select topics in the physical and life sciences to bring out our conception of the important structural features of science as a basis for an elementary school science program (2). "Structural features" refers to the general underlying principles that have made science the analytical tool that it is, and includes the experimental methods that have brought these principles to light.

(b) To promote in children the learning prerequisites of Vygotsky (3) viz., deliberate attention, logical memory, and ability to compare and differentiate.

(c) To determine by experimentation, the appropriate topics, learning level, and language for the presentation of this program to the pupils.

(d) To determine the effect of the topics presented on pupils and teachers involved in the program.

(e) To make the tested materials available to teachers through teacher manuals and to develop readers on the topics developed.

(f) To explore the possibilities for in-service or summer teacher and supervisor training courses and classroom television programs.

The project grew out of discussions in the spring of 1962 when several scientists began to consider the type of science they wished their own first-grade children to learn. The initial group was comprised of a biologist, Austin Haws (later replaced by Reed Roberts, biologist); a mathematician, Robert Hammond; a physicist, John Wood (Director of the Project); and a science educator, A. L. Braswell. Dr. Wood and Dr. Braswell proceeded with exploratory lessons in the classroom and the results of these explorations formed the basis of the first summer writing project. Two first-grade teachers of the Logan City Schools, Mrs. T. Taylor and Mrs. J. A. Couch adapted the notes of the principal investigators to the level of first-grade pupils and wrote lessons with appropriate activities and explanations. These lessons with necessary equipment were submitted to five Logan City first-grade teachers for trial during the 1963-64 school year and then rewritten in the summer of 1964 incorporating many helpful suggestions from the trial teachers. Currently, the curriculum is again undergoing trial on an experimental basis in all the 14 first grades of the Logan City School system, thus involving the participation of teachers and four hundred pupils. The project team is in the process of developing an instrument to test the effectiveness of the program. We concur with the judgment of Atkin (4) re: "Evaluation of These Programs," that the objectives of this type of curriculum, being process oriented, present a real challenge for evaluation.

Our program addresses itself to leading the pupils through a series of experiences which will result in behavioral changes in both pupils and teachers. An evaluative instrument must be constructed which will discriminate between glib verbalization and actual practice of the behaviors and attitudes of a scientist. Extensive knowledge of the myriad of facts unearthed by scientific endeavor can be quite readily tested by simple fact-oriented paper and pencil tests. However, to ascertain quantitatively the extent to which a first-grade pupil has incorporated certain desirable behaviors into his approach to solution of new problems is, admittedly, a highly ambitious undertaking. Nevertheless, barring unforeseen complications, it is planned that completion and standardization of such an instrument will be realized by the summer of 1965.

## Materials for Teachers

*Science for First Grade* provides a curriculum for the entire year if the lessons are taught two to three times each week with lessons ranging in duration from thirty minutes to one hour each. Printed materials thus far produced consist of a teacher's manual of basic lessons and a cross-referenced pretrial teacher's manual, *Biological Supplement* to complement the basic lessons.

A second-grade program built upon the foundation laid by the first-grade lessons was started in the summer of 1964 and is being adapted for presentation at this level.

In the organization of the sequence of the activities, an attempt has been made to observe a hierarchy of competencies commencing first with the skill of observation. Motivation for engaging all the senses in observation activities is supplied through the presentation of a variety of "Puzzles." These puzzles range in nature from simple observation of similarities and differences of color, size, shape, and location of wooden blocks to the abstract and complex puzzles of matricies and Venn diagrams.

Pupils are led to develop a deliberate consciousness of the use of all senses. Subsequent lessons utilizing a dialectic approach on the part of the teacher provide stimuli for each of these senses encouraging pupils to expand the respective

**A limited supply of the 114-page Trial Edition *Science for First Grade* and 45-page Pretrial Edition *Biological Supplement* are currently available to interested persons. Inquiries should be addressed to the author.**

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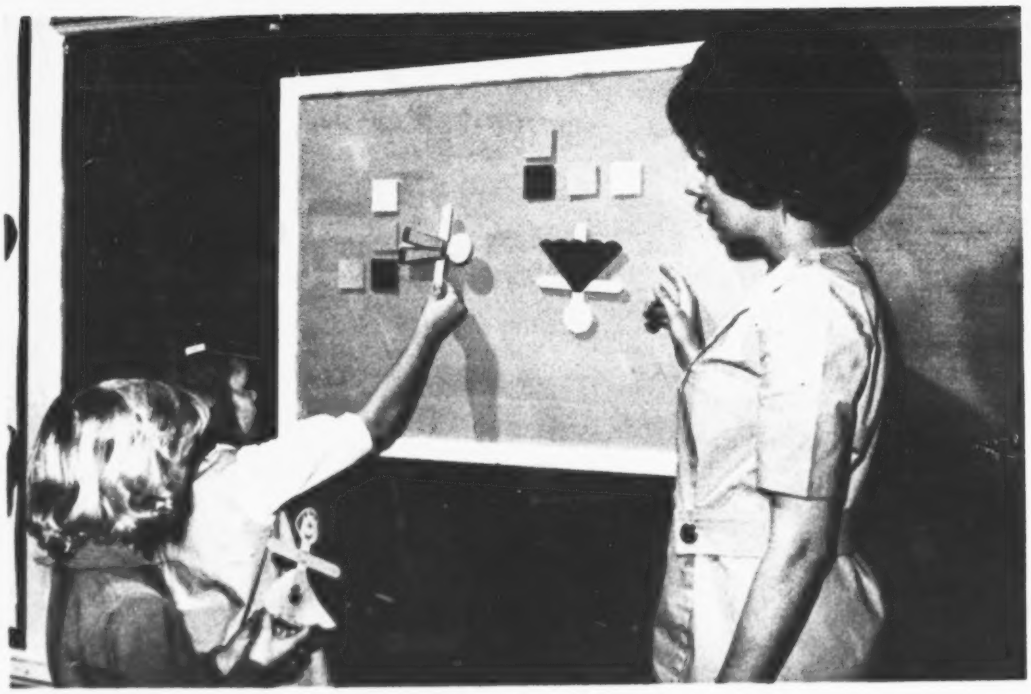
[1] The Elementary School Science Project, of Utah State University, Logan, Utah, Director John Wood, is made possible by a two-year grant awarded through the Course Content Improvement Section of the National Science Foundation.



*Systems and interactions are studied by these first-grade students.*

ranges of these perceptive skills both qualitatively and quantitatively.

Lesson topics in the program include the following:

**First Grade**

- Concept Games
- Solving Puzzles (general observation of objects)
- Solving Puzzles (specific observations)
  - Seeing
  - Hearing
  - Touching
  - Smelling
  - Tasting
- Changes
  - Observing changes (detectable by each of the senses)
  - Measuring changes
- Systems and Interactions
  - Objects in a system
  - Interactions of objects
  - Changes in interacting objects
  - Classification of similar and different interactions (light, acoustical, electrical, magnetic, elastic, friction)

**Second Grade**

- Solving Puzzles (review)
- Systems and Interactions (review)
- Interactions
  - Measuring strengths of interactions
  - Graphing interaction strength (coordinates)
- Experimentation
  - Models of nature
  - Controlling interaction of objects
  - Keeping records
  - Detecting patterns in data

The pretrial First-Grade Biology Supplement is cross referenced with the basic *Science for First Grade* manual. It represents an attempt to incorporate the nine unifying themes of the Biological Sciences Curriculum Study (BSCS)[2] into lessons appropriate for presentation to first-grade pupils. The activities build upon the foundations laid by the basic lessons and provide an extension and practice of these processes (viz., observation, classification and measurement of objects, systems, and interactions) in real life. Pupils are encouraged to explore their environment and associated species of plants and animals with "awakened and sharpened" senses. Numerous truly exploratory experiments are included to provide an opportunity for pupils to inductively arrive at conclusions. Discovery and identification of the interactions of plants or animals with heat, light, water, or nutrients respectively, provide practice in designing an experiment and executing many of the skills employed by the scientists. The units in the manual include:

- Observing
- Classification
- Growing Plants
- Microscopic Life

*Science for First Grade* is designed as a manual for the teacher only and includes objectives, materials, methods, explanations, and illustrations. Teacher and pupil resource materials including reference books, films, filmstrips, and charts have been indicated where appropriate.

Into the framework of the above topics, attempts have been made to incorporate and adapt numerous important contributions of other similar projects throughout the country, synthesizing them into a meaningful sequence of ideas and hierarchy of competencies.

Since these activities promote primarily processes and skills, elementary school teachers are spared the threat formerly imposed upon them by the "fact-oriented" traditional science curriculum. They can comfortably engage the pupils in the "puzzle-solving" activities free of the haunting fear of their having forgotten the conglomeration of scientific facts from their meager exposure to a predominantly descriptive science.

Effective elementary school teachers have consistently maintained their equilibrium and remained aware of the following: (1) That they have to teach *all* the children; (2) A very small percentage of those pupils will actually engage in scientific research, and it should follow that a proportionate amount of school time should be thus spent. It is the studied contention of this investigator, however, that taught as a human endeavor, the scientific endeavor can contribute significantly in innumerable ways toward the fuller and better or "self-actualized" life of the pupils. If, according to Coombs (5) it is allowed that the degree of one's self-actualization is directly proportioned to the quality of four characteristics of his perceptual field and "these characteristics are: *a.* a positive view of self, *b.* identification with others, *c.* openness to experience and acceptance, and *d.* a rich and available perceptual field," *Science for First Grade* is highly indispensable.

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[2] The nine unifying themes are: (1) Change of living things through time; evolution, (2) Diversity of type and unity of pattern in living things, (3) The genetic continuity of life, (4) The complementarity of organism and environment, (5) The biological roots of behavior, (6) The complementarity of structure and function, (7) Regulation and homeostasis; preservation of life in the face of change, (8) Science as enquiry, and (9) The history of biological conceptions.

"A positive view of self" can be acquired only as these pupils find themselves, as Kelley(6) designates it, "enough" to cope with not only other people but also with their tantalizing relationship to their environment. Engagement in activities designed to promote successful, independent explorations of their environmental phenomena relying strongly on one's own perceptual skills fosters a feeling of adequacy.

The direct manner in which this curriculum can contribute toward a "rich and available perceptual field" is perhaps the most evident. A close scrutiny of the lessons provided will disclose the fact that approximately 90 percent of the activities serve to help a pupil perceive more fully to whatever he is exposed. He is led to see not only the object before him, but also its shape with an awareness of its comparative size, its color, relative position, quantity, possible interaction with other objects, strength of its interaction, etc. Through practicing this kind of expansion of the scope and quality of all perception and utilization of mechanical extensions of all the senses, the pupil will enjoy a greatly enriched perceptual field.

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3. L. S. Vygotsky. *Thought and Language.* John Wiley and Sons, Inc., New York City. 1962. p. 82.
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5. A. W. Coombs. "A Perceptual View of the Adequate Personality," *Perceiving, Behaving, Becoming, A New Focus for Education.* Yearbook, 1962, Association for Supervision and Curriculum Development. NEA, Washington, D.C. p. 51.
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# Science Is for the Senses

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In some respects, the state of contemporary science education seems to be a projection of *Lost Horizons* where beauty abounds. It is widely known and fully appreciated that learning in science involves active participation rather than passive exposure. The recent literature in science education with its emphasis upon induction, discovery, structural configuration, and distinction between process and content has served to make activists out of all science education theorists. All classroom teachers of science have been transformed into laboratory supervisors, resource persons, and catalysts for individual experimentation. But, alas, one must leave Shangri-La to enter a school classroom.

### Theory and Reality

Within the realm of elementary education there is little evidence to support any of these contentions. While the observer of science instruction in elementary school classrooms may be impressed by the zeal of the teacher, and while he may sense a certain insecure willingness on the part of the teacher to conform to the "modern" expectation, he is likely to be most impressed by the extent to which science instruction continues to bear the stamp of authoritarian didactics.

In many classrooms the children, with good reason, react to science with boredom or even more negative feelings. They typically seem to resent the lack of personal participation in activities which involve their senses directly.

Jean Piaget, the renowned developmental psychologist, presented his position on classroom instruction during his recent visit to the United States. He said, "The goal in education is not to increase the amount of knowledge, but to create the possibilities for the child to invent and discover . . . Teaching means situations where structures can be discovered; it does not mean transmitting structures which may be assimilated at nothing other than the verbal level." (1)* This view is further elaborated by Lovell (2) in his discussion of thought and action.

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* See references.

He holds that thought arises from actions, and concepts arise out of the actions which children perform with objects and not from the objects themselves.

Among those concerned with improvement of science education and for whom this activity-oriented instructional philosophy has appeal, at least two major courses of action come to mind. First, it would seem that the science program could be materially improved if scientists introduced teachers to the philosophy of experimental science; and the teachers, in turn, chose to transmit this philosophy to children. While such a course of action has some merit, it has three apparent weaknesses. Transmitting this philosophy to approximately one million elementary school teachers in the United States presents an apparently insurmountable obstacle. Even if such an accomplishment were feasible, it must be appreciated that experimental science has a substantial content. The philosophy probably cannot and should not be presented in the absence of a long term consideration of science content. It is doubtful that the philosophy of experimental science can be transmitted through verbal communication in any case. It is likely that the teachers must experience the philosophy and method of experimentation through active participation in science, in the same manner that it is hoped children will experience these attributes in their program.

A possible second course of action for improving science education concerns revision of the program itself. The course of study may be modified so as to include many fertile opportunities for children's active involvement. It may be modified so that it includes possibilities for children to come to grips with some of the fundamental concepts of science rather than with trivial interpretations of phenomena or the social virtues of science. It may be modified to include the philosophy of experimental science in an atmosphere of challenge, interest, and excitement.

It was upon this second course of action that the University of California Elementary School Science Project embarked in 1959. The ultimate purpose of this project is the improvement of science education at the elementary school level. Through experimentation in elementary school classrooms, answers to the following questions are sought:

1. Can the professional research scientist make a contribution to the elementary school science program which is acceptable and useful to teachers at this level?
2. Can materials be developed which emphasize fundamental science concepts and, at the same time, hold the interest of elementary school youngsters?
3. Are the methods of basic science suitable for the elementary school setting?
4. What is the grade or what are the grades at which introduction of certain science concepts produces the best result?
5. Can children be actively involved in the manipulations and procedures of experimental science?
6. Can science be made more stimulating and interesting to elementary school children and teachers?
7. What experiments and instructional procedures are most effective in promoting children's understanding of particular science concepts?

From a modest beginning involving four members of the University of California faculty, the project has included a total of twenty-one faculty participants. Each has contributed in some way to the project activity though not all have participated directly in the preparation of curriculum materials.

The curriculum research proceeds according to a general pattern, within which individual variations are common. After the scientist identifies those fundamental science concepts within his discipline which may lend themselves to treatment at the elementary school level, he begins to prepare a unit of instruction about them. In this preparation, he is usually assisted by a teaching consultant (an experienced elementary school teacher), a technical writer, and an evaluator. The scientist's working outline is expanded to include fruitful classroom activities which involve children to the maximum extent possible. In addition to suggesting some of these activities, the teaching consultant often determines their potential worth through actual trial in an elementary school classroom. She may teach a particular lesson or guide some children through a given experimental activity several times before it is finally reduced to written form. Once a series of lessons is developed to the satisfaction of the scientist, the technical writer is called upon to prepare a written unit of such form that it may be used in a trial evaluation. This preparation includes not only the suggested instructional program for children but also provides the public school teacher with a sufficient content background to maximize teaching success. The unit also includes complete descriptions of equipment to be used and detailed directions for guiding the children's experimental activity.

The first classroom trial of a unit is usually held in twelve to eighteen elementary school classrooms. This trial is commonly undertaken in the University of California Laboratory Schools. It is the purpose of this pilot test to assess all possible aspects of the interaction between the experimental program and children. Teachers are asked to comment critically on all phases of the program. They are asked to assist with decisions regarding proper grade placement of the material, whether certain activities should be included or omitted, whether the sequence of activities is reasonable, and whether the concepts covered are or can be made attractive to young children. Children's learning is evaluated through tests of various kinds, and a thorough analysis is given to the objective test data. Children's conceptual development is often observed by the scientist as well as by other members of the project staff. Both objective and subjective evaluations are synthesized into a report of the trial. This report, supplied by an evaluator, usually includes specific recommendations for the modification of the unit.

On the basis of these recommendations and the generalized impressions gained from observing children and teachers in action, the unit is revised. The revision is often drastic at this stage. Most units are subjected to two or more such trials before some broader evaluation is undertaken.

When it is felt that the local experimentation has been sufficient, the units are prepared for wider distribution. At this stage, the original unit has usually been divided into several parts, each designed for a particular grade, or grades, in the elementary school and each contributing to the total sequential, conceptual development. The materials are distributed, at cost, to approximately one thousand interested teachers beyond the range of project supervision, and these teachers are encouraged to complete summary evaluation reports regarding the use of the material in their science programs. As data from these reports are accumulated, additional revisions may be dictated.

### Scientific Accuracy Assured

In all of the experimentation, the scientist plays an autonomous role. While the effort as described is clearly cooperative in all its phases, the final authority for development and change rests with the university scientist. In this manner scientific accuracy is insured, and the flavor and philosophy of experimental science are protected.

The nature of the project has permitted investigation into many science areas. While it is impossible to indicate the detail of the individual investigations, the scope of the activity is revealed by the following summary of activities of the University of California Elementary School Science Project. The list includes activities to date together with activities under way for the current year, 1964-65. Included with each activity are the names of the principal investigators responsible. (Some of these men are no longer associated with the project.)

ZOOLOGY — *Animal Coloration.* Robert Stebbins, Professor of Zoology.

The material has been extensively tested, beginning in the fall of 1960. It will be distributed in the form of four units for grades 4, 5, and 6 entitled "Animal Variation," "Principles of Concealing Coloration," "Principles of Advertising Coloration," and "Natural Selection."

BOTANY—*Plant Morphology.* Herbert Mason, Professor of Botany.

This unit is concerned with the external characteristics of seed plants. It has the additional goal of inducing the children to develop a logical classification scheme for their observations. Some extensive sequences of lessons have undergone preliminary trial on three different occasions and the preparation is continuing. The material will be submitted to formal trial during the present school year.

PHYSIOLOGY—*What Am I?* Nello Pace, Professor of Physiology; Arthur Pardee, Associate Professor of Biochemistry; and Robert Macey, Associate Professor of Physiology.

An introduction to some of the basic physiological components of the human body. The original material on human physiology and biochemistry was first tested in 1960. Revisions and trials, since the early test, have tended in the direction of reducing the material on biochemistry and partioning the material on physiology. At the present time four different units entitled, "How I Began" (embryology), "How I Move" (skeletal and muscular systems), "How I Know" (nervous system), and "How I Keep Alive" (metabolism) are in various stages of preparation.

ECOLOGY — *Population Dynamics.* Robert Stebbins, Professor of Zoology.

The instructional program on the topic of population growth introduces children to the mechanics of population control in the animal kingdom and alerts them, through analogy, to the cruciality of the problem of uncontrolled population growth in any animal society. The unit is in the initial phase of preparation.

PALEONTOLOGY — *The Evolution of Life.* Charles Camp, Professor of Paleontology.

Through a series of historic narratives, the children are familiarized with the evidence concerning the changing life forms which have inhabited the earth and are acquainted with the discovery methods of the paleontologist. The unit is now being readied for a local trial.

ENTOMOLOGY — *Insect Life.* Harold Madsen, Associate Professor of Entomology.

Professor Madsen has expressed an interest in the preparation of material on insects but actual preparation has not begun. Various possible topics are under consideration.

GENETICS — *Heredity.* Patricia St. Lawrence, Assistant Professor of Genetics.

Predictability of animal and plant characteristics through study of genetic components. The unit is in the early stages of preparation. A teacher's background manual on genetics will be completed this year.

PHYSICS — *Force.* Robert Karplus, Professor of Physics.

A unit on force to acquaint children with Newton's Laws of Motion. (Work on this unit has been suspended.)

*Gravitation and Buoyancy.* Owen Chamberlain, Professor of Physics.

The work on this unit is now in suspension until adequate time and resources for its development are at hand.

*Wave Motion.* Roger Wallace, Research Physicist.

Properties of commonly encountered waves. Progress on the unit has continued through several revisions, and it is currently undergoing trial.

CHEMISTRY — *The Structure and Properties of Matter.* Chester O'Konski, Professor of Chemistry. Assisted by Leo Brewer, Professor of Chemistry; Charles Koch, Associate Research Chemist; and Albert English, Associate Professor of Electrical Engineering.

The molecular theory and its relationship to the composition of matter. The nature of atoms and their arrangement within substances is explored by the children. The unit has undergone extensive testing, and it is planned that another evaluation shall proceed soon.

MATHEMATICS — *Coordinates I.* Robert Karplus, Professor of Physics.

A unit on the mathematics of science. Children were taught about the Cartesian coordinate system, the use of this system in the graphing of physical behavior, and the alternative description of relationships through the use of equations. The work on this unit was suspended after the local test was completed.

*Coordinates II*. Stephen Diliberto, Professor of Mathematics.

This second preparation of coordinates material was designed to acquaint the children with applied mathematics. The usefulness of the Cartesian coordinate system in scientific description was exploited to the extent possible, and concrete rather than abstract expression of the mathematics was emphasized. After extensive local testing, the material was prepared in four units as follows:

Part I — The Description of Position on Lines and Planes (Grades 2-6)

Part II — The Graphical Depiction of Physical Quantities (Grades 3-6)

Part III — Equations of Straight-Line Graphs (Grades 5-6)

Part IV — Equations with Negative Slopes and Intercepts (Grade 6)

The broader evaluation of these materials is in progress. Additionally, workbooks for use by the children are being prepared.

While the above description of activities include important information about the project, it fails to present adequately the accumulation of valuable experience and information which has been accrued by the active participants. There is no theoretical exercise or abstract formulation which can substitute for the experience of dealing with real experimental science for real children in real schools. The curriculum experimentation and the extensive experience have produced sound bases for some important, if not profound, observations:

1. The professional research scientist can and does make a substantial contribution to the improvement of elementary school science.

2. A cooperative enterprise involving scientists, educators, and writers can develop science programs which involve children and which hold their interest.

3. The methods of experimental science can usually be adapted to the elementary school setting, and children can develop an ability to use these methods.

4. An active involvement on the part of the child is necessary in most fruitful science activities.

5. The development of effective instructional outlines for the elementary school level is a difficult but absorbing enterprise.

6. Repeated trial and evaluation is a necessary component of elementary school science curriculum development, and is, of course, crucial to investigations into children's learning of science concepts.

While there are no panaceas in the task of improving elementary school science instruction, there is a principle which warrants particular attention. If science is to mean something other than a class lecture period or pages of factual material in a textbook, young children must be involved in it. To recite the virtues of the scientist in his laboratory, or to tell children that experimentation is fun and productive is grossly insufficient. Even the display of an experiment performed by the teacher falls short of the mark. To the greatest extent possible, all of the senses of the child must be involved if the flavor of science is to be known. There is no known way to obtain such involvement short of the child's direct participation. In designing a science program for the elementary school, the first and most important part of the equipment for any activity is the child himself.

## References

1. Jean Piaget. Conference at Cornell University, Ithaca, N. Y. 1964.

2. K. Lovell. *The Growth of Basic Mathematical and Scientific Concepts in Children*. Philosophical Library, New York City. 1964. p. 18.

# SCIENCE SYMBOLS —

# A Key to Understanding

**JAMES LATHAM**

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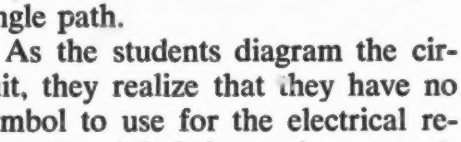
A sixth-grade class has just been introduced to a new science experience. Fifteen miniature Christmas lights glow brightly in the front of the room. Members of the class see only a wire that is plugged into an electrical outlet and the glowing bulbs. One of the bulbs is removed from the set and all of the other bulbs go out.

Almost in unison the class responds with, "There's only one path!"

"How do you know?" asks the teacher.

Dorothy replies, "Because that is how they acted when I connected some to a battery on a single path and removed one."

The teacher seeks volunteers to come to the front of the room and diagram the circuit on the board. The maze of wire and bulbs is reduced to a diagram by one of the students.



Holding up the string of lights, the teacher asks if anyone would care to examine it. No one chooses to look, they are sure that there is only a single path.

As the students diagram the circuit, they realize that they have no symbol to use for the electrical receptacle. All their previous experience has been only with flashlight batteries and bulbs. They also want to know if they can light one of the Christmas bulbs with batteries and how many they will need.

Penny suggests, "If you use enough batteries to light another bulb to the same brightness, that will tell you how many are needed to light each one."

Joe interrupts, "And if you multiply the number for one by the 15 bulbs, you will know how many you need to light them all."

There seems to be general agreement with the suggestions made. One of the boys rushes to close the blinds. A red bulb, using dry cells as a power source is to be compared with a red bulb using the electrical power source of the school. One battery is connected to the bulb being tested and compared to the control—"dim, not enough." Another battery is added, still not as bright as the standard.

"Keep adding batteries."

A third battery is added, "That's better, but it's still not enough."

The fourth battery is now added. At this point, interest seems to reach a peak. Some believe four to be enough, others feel that another battery is needed. Reluctantly, on the part of some and anxiously by others, the fifth battery is added.

"That's it," comes a shout from a majority of the class. Some say, "It's too many."

"You can't divide a battery," says one student.

The students make their choices and multiply to determine how many batteries to include in their diagrams that are necessary to light all 15 bulbs. (*NOTE:* If the five 1½-volt batteries, selected by the majority, are multiplied by the 15 bulbs, they need 75 batteries or 112½ volts. The circuit is rated for operation between 110-120 volts.) Thus, their observations and use of electrical symbols make some basic understandings of the electrical circuit real and meaningful to the class.

This is quite complex reasoning for elementary school children, but responses of this order are becoming more and more frequent in a typical sixth-grade class at the Lone Oak Elementary School, Rockville, Maryland. Their science unit, "Batteries and Bulbs II" has been developed by the Elementary Science Study of Educational Services, Incorporated, Watertown, Massachusetts. Benjamin Nichols of the School of Electrical Engineering of Cornell University has been the scientist behind the scenes in the development of the unit. This unit is also under trial in the Central School, Ithaca, New York.

Let us examine what there is about this science experience that enables these youngsters to comprehend and think on this higher cognitive level.

The materials seem to have two qualities that help the children gain insight and understanding into the nature of electrical circuitry. First, there are simple, inexpensive materials for all students to use. They can combine the materials in many ways and make several observations about the behavior of the different combinations of objects. Second, and possibly more important, the children can translate their observations into electrical symbols. The symbol then becomes a way of describing what they have done and what they have observed. Furthermore, the use of symbols makes it possible for the students to reconstruct their experiences from the concrete to the abstract and from the abstract to the concrete. Words are not stumbling blocks since all students begin to learn this new language form as equals. Reading difficulties do not close the child's door to success. One's observations supply the facts and the new symbols make it possible to communicate these facts.

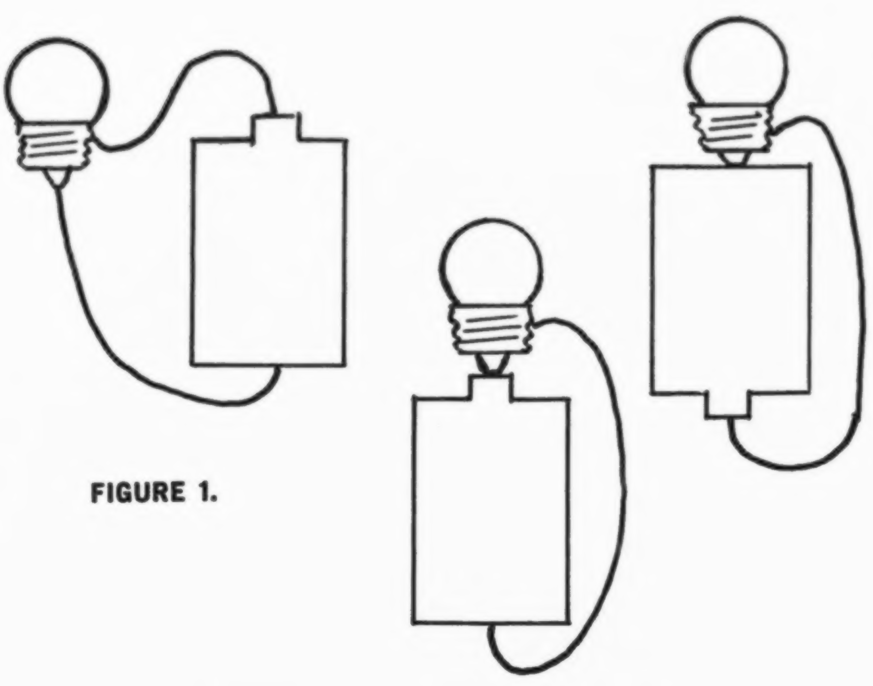


FIGURE 1.

Let us examine a few of the materials and situations that lead to the use of the symbol and this type of complex reasoning. All the children are given a flashlight bulb, a flashlight battery, and two pieces of copper wire. The only directions given are to use these materials to light the bulb. It is soon discovered that there are several ways to combine the materials to light the bulb. The children begin sharing their discoveries with one another. Picture records are kept of the combinations that light the bulb. (Some of these drawings are shown in Figure 1.) By carefully examining the pictures, one readily sees a pattern emerging. The students notice this and talk about this emerging pattern.

"There are special places that must be touched."

"It's like a path."

"The bottom and top of the battery must touch the side and tip of the bulb."

Upon careful examination, the children suggest:

"A bulb is like a thin wire."

"It's like a thin wire inside of glass."

"The special places on the bulb are connected to the thin wire."

Thus, the bulb's contents are exposed and reason is established for touching its special places. The pictures are next reduced to a series of symbols. See Figure 2. When the symbols are connected to show the path, they look like those in Figure 3.

FIGURE 2.

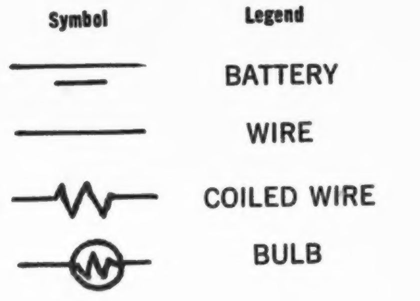
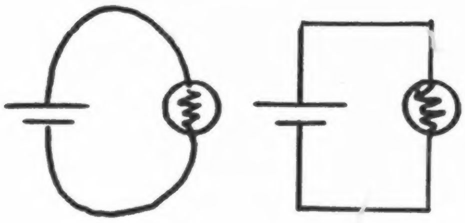
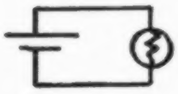


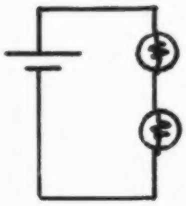
FIGURE 3.



When given an opportunity to connect more than one bulb to their battery and asked to record their work in the new symbolic form, the pupils record interesting combinations. Their manipulation of the objects and analysis of their observations recorded in electrical symbols, unveil the behaviors of series and parallel circuits:



"There is one battery and one bulb on a single path."



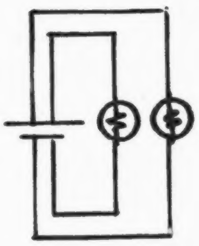
"There are two bulbs and one battery on a single path."

"If you take out one of the bulbs, the other goes out."

"They are dim."

The children soon begin to compare the brightness of the bulbs using the first combination of materials as their standard. The brightness of the bulb is then measured as brighter than, as bright as, or dimmer than the standard.

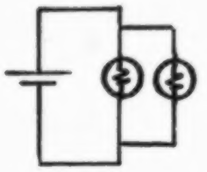
Using drawings to represent different paths and different bulb brightnesses, the children observe:



"That's two bulbs and each on a separate path."

"Each is as bright as the standard."

"One bulb stays lit when the other is removed."



"Two bulbs on a divided path."

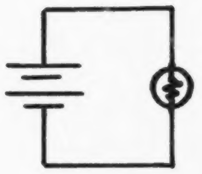
"Standard brightness."

"Remove one and the other stays lit."

It is at this point that the students begin to compare the patterns as single paths, separate paths, and divided paths. Soon Debbie makes this observation. "If you have more than one bulb on a single path to one battery, it will be dimmer than the standard. If you have more than one bulb on divided paths or have a separate path for each bulb, then they will be standard bright."

What better understandings of series and parallel circuitry could one ask for from young children? Debbie's statement soon becomes accepted and is used by the class to predict what would happen when a battery is connected to bulbs. They even speak of it as Debbie's Rule.

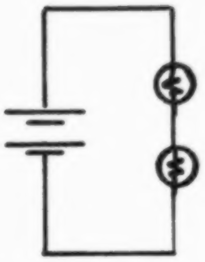
When additional batteries are added to the circuits, new sets of ideas come forward. Let's look at only one of the many possibilities that arise.



"Very bright."

"Brighter than standard."

"Acts like more than one battery."



"Standard brightness."

"Acts like one bulb and one battery on one path."

"If one bulb is removed, they all go out."

The students explore the possibilities of using equal numbers of batteries and bulbs on the same path and there is general agreement that if there is only one path for the batteries and bulbs, there must be one battery for each bulb if you are to have standard brightness.

It is at this point that the Christmas lights experiment is introduced.

## Summary

What then, are the possibilities for the use of science materials which permit observation and manipulation by all children? Are there symbols in other areas of science that can open doors of scientific understanding for young children? These certainly are questions worthy of consideration by teachers and curriculum study groups as they develop science experiences for young children.

# # #

# ASTRONOMY

# For Grades Five Through Eight

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The University of Illinois Elementary-School Science Project is an astronomy sequence for grades five through eight that delineates certain major concepts intended to assist the student to perceive the basic structure of the subject. By concentrating on the intellectual power of a few pervasive ideas in astronomy, a cogent entity is developed, rather than a description of loosely connected facts and phenomena. "Process" goals that characterize certain elementary-school science programs are also emphasized. In particular, project books stress the development of a rational argument for a scientific idea, rather than assertion.

During the summer of 1964, nineteen astronomers, science education specialists, and teachers participated in the fourth summer writing conference of the Project. A brief description of the six books written during these conferences illustrates the topics by which the unifying ideas of the astronomy sequence are presented.

Book 1, *Charting the Universe*, covers such topics as measurement, distances in the solar system and beyond, the size and shape of the earth, and the inverse square law applied to light as a tool for determining great distances. Book 2, *The Universe in Motion*, outlines conceptual models to account for observed motion. The student is introduced to geocentric and heliocentric perspectives. Book 3, *Gravitation*, deals with such concepts as velocity, acceleration, mass, and force. The focus of Book 4, *The Message of Starlight*, is on methods astronomers use in analyzing starlight to obtain information about the composition of stars. The emphasis in Book 5, *The Life Story of a Star*, is stellar evolution. Book 6, *Galaxies and the Universe*, introduces the student to our galaxy, other galaxies, and cosmology. Astronomy is an outstanding instance of an interdisciplinary field in the physical sciences. Concepts of physics, mathematics, physical chemistry, and geophysics are essential features of each book.

The first three books have had extensive trial in schools all over the country. The classroom situations were in public and private schools; suburban and urban schools; segregated and nonsegregated classes. The teachers varied widely in science background. Science consultants, principals, or teachers served as local project coordinators and also gave assistance to individual teachers as needed.

Book revision has been based on the reactions solicited from cooperating teachers both in writing and through interviews. Members of the Project staff observe extensively in classes where the materials are being tried to supplement written teacher reactions. Numerous conferences are held with participating teachers. Judgments are also invited from scientists who have not participated in the summer writing conference.

The testing phase of Book 1, *Charting the Universe*, and Book 2, *The Universe in Motion*, and their teacher's guides have terminated. Enough data from teachers and consultants were accumulated to develop an edition of these books that will stand for the present. Book 3, *Gravitation*, was revised in 1964 on the basis of reactions from over 300 teachers who tested the materials during the 1963-64 school year. The teacher's guide for *Gravitation*; Book 4, *The Message of Starlight* and its guide, are now in trial edition form and are being tested in classrooms during 1964-65. Substantial preliminary writing has been completed on the remaining books in the series, but Books 5 and 6 will not be submitted for extensive classroom trial until 1965-66.

Certain evaluation activities have been initiated that extend beyond book revision. The Project is interested in certain long-range effects of the books on children—how their viewpoint of science and scientists may have been modified, for example.

The Project has been supported since 1960 by the National Science Foundation. Co-directors are J. Myron Atkin, Professor of Science Education, University of Illinois and Stanley P. Wyatt, Jr., Professor of Astronomy, University of Illinois. Senior authors for the series are Henry Albers, Astronomy Department, Vassar College (Book 1); Karlis Kaufmanis, Astronomy Department, University of Minnesota (Book 5); Benjamin F. Peery, Astronomy Department, Indiana University (Book 4); Gibson Reaves, Astronomy Department, University of Southern California (Book 6); and Stanley P. Wyatt, Jr. (Books 2 and 3).

# MINNEMAST

# The Coordinated Science And Mathematics Program

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"But seed coats don't have zippers," cried the young botanist, with a hurt look in his eyes. He was discussing a question about a story of the germination of a bean seed with the story's author, a professional children's story writer. The writer was visibly disturbed that young children would gain a misconception about bean seeds. The problem was resolved to both parties' satisfaction by changing the terminology.

The above was one of many similar incidents that occurred during the 1964 MINNEMAST Summer Writing Conference held at the University of Minnesota. MINNEMAST, Minnesota Mathematics and Science Teaching Project, is a National Science Foundation sponsored curriculum project for mathematics and science in the elementary school. During the 1964 summer writing conference, a composite group of eighty educators, scientists, mathematicians, psychologists, children's writers, science writers, artists, librarians, a musician, a historian, and college elementary education majors pooled their ideas, talents, and efforts to lay the groundwork for a coordinated science and mathematics program for kindergarten through ninth grade.

### Coordinated Program

A science program which makes use of mathematics skills will add to the child's capacity to gain a quantitative and deeper understanding of his physical and biological environment. In reciprocal fashion, the science program can serve to initiate and develop concepts of mathematics. This type of science program can provide the opportunities and emphasize the necessity of using mathematical skills. If young children are encouraged to examine critically the intimate relationship between science and mathematics, it should be possible to teach these children both mathematics and science in greater depth and understanding. Thus, the principle of a coordinated science and mathematics program for kindergarten through grade nine appears not only to be logical and practical, but mandatory. The National Science Teachers Association (NSTA) position on this subject is as follows: "Efforts in science curriculum development should be accompanied by corresponding developments in mathematics, and the two must be closely correlated at all levels." [1]

The emphasis of the MINNEMAST science program is placed upon the activities of scientists—what they do; how they think; how problems are approached and solved; and how these activities lead to prediction, new problems, and new experiments. The MINNEMAST program does not have as one of its objectives the teaching of the "scientific method" in the all too familiar way. Instead, the program is keyed to the operations of science.

### Operations of Science

Recent studies by psychologists and learning theorists have shown the importance of personal observation of objects in his environment and experimentation by the child. While results appear favorable, they also indicate that additional studies should and must be considered. It would seem only logical then, to extend observation and experimentation by encouraging active student participation into other fundamental processes of science as much as possible.

The MINNEMAST Science Program has conveniently classified the operations of science into the following: Observation, Measurement, Experimentation, Description, Generalization, and Deduction. While other processes may be equally suitable, these seem useful as a point of departure. The operations of science, as listed above, are clearly interrelated and interwoven. It then becomes evident that an activity in such a program will involve not

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This article was prepared from the writer's experiences as a participant in the MINNEMAST Summer Writing Conferences, and from a working document prepared by the MINNEMAST Science Advisory Committee.

[1] "The NSTA Position on Curriculum Development in Science." *The Science Teacher,* 29:32-5. December 1962.

one, but several of the operations of science.

The problem of developing for the child the operations of science in appropriate teaching units is by no means a simple one. In fact, the success of the program is dependent upon the manner in which this is done. There is more to the operation of *Observation* than just training children to be observers. The operation of *Description* implies more than teaching children to give reports of their observations. The operation of *Experimentation* is much more than the duplication of some scientific experiment. It is therefore evident that if the operations of science framework are to be developed into a sound science program, a logical, complete, and sequential series of teaching units must be achieved.

### Sequential Units

The MINNEMAST sequential teaching units may be best illustrated by tracing the development of the operations of science through several units. A kindergarten unit encourages the child to disregard most of his physical and biological surroundings and to focus his attention upon simple objects one at a time. The children actually collect their own objects while participating in an "object hunt" activity either on the playground or on a walk through the neighborhood. Examination of the collected objects provides an observational technique that permits full use of the child's sensory equipment in a productive way. The child is then asked to sort the objects into groups called sets (mathematics program reinforcement). This forces the child to focus his attention on the properties of objects. He may place the objects into sets according to size, color, function, etc. A description of the object is then made in terms of its properties.

This type of *Observation* and *Description* approach is extended much more fully a year later in a first-grade unit emphasizing the properties of objects. A later first-grade unit places two or more objects into a system. Again the child is encouraged to ignore the objects outside the system. Here the child is confronted with the problem of the function that each object performs in the system. Experimentation begins when the child changes the initial state of a system in another first-grade unit and observes corresponding changes in its final state. A second-grade unit on variation of objects requires the child to employ basic techniques of *Measurement*. A later second-grade unit requires the child to employ data gained from measurement to predict the height of plants at a given future time.

As briefly indicated, various scientific operations are developed into sequential units that make clear some of the more detailed aspects of these operations and, in addition, exhibit some of their interrelationships.

### Spiral Structure

The MINNEMAST science curriculum is based on a spiral structure. The structure is not based on the familiar repetition of subject-matter topics that one finds in the usual curriculum of this type. The MINNEMAST spiral is based on the operations of science as mentioned earlier: Observation, Measurement, Experimentation, Description, Generalization, and Deduction. The first "loop" of the spiral would include grades kindergarten through grade two. In this loop, the child will gain some experience in all of the listed scientific operations. The child's objective in this loop is to gain a modest overview and limited experiences in the entire structure of scientific activity. As a result, sequential activities in the next loop will have more meaning when they can be related to the overall structure.

Although the kindergarten-second grade loop contains all the operations, its greater emphasis will be with *Observation* and *Description*. As new units of the succeeding loop for grades three and four are developed, the emphasis will perhaps shift to *Measurement* and *Experimentation*. If this trend continues, the fifth-sixth grade loop would conceivably emphasize *Generalization* and *Deduction*. The reader should be reminded again that all loops will be represented by experiences in each of the six operations of science. The emphasis will change according to the needs of the child and the sequence of the program.

The objective of the MINNEMAST science program is to provide the child with a way of getting at information he seeks. The intellectual tools needed by the child can be compared to those needed by the scientist. The tools are really step-by-step schemes that the child can use discovering relationships and developing understandings.

The MINNEMAST science program has attempted to incorporate the findings of the Swiss child psychologist, Jean Piaget,[2] into the curriculum. The brevity of this article prevents a just discussion; but, briefly, Piaget's findings indicate the sequence in the manner concepts are constructed by the child.

It is expected that children involved in the program will actually obtain more information in an incidental way than those exposed to an information-oriented curriculum. Children will acquire knowledge only for the purpose of winning new knowledge. Factual information unrelated to the purpose has little value. Children will instead learn fundamental operations common to all science.

### MINNEMAST'S Future?

The MINNEMAST program is just one of perhaps a half dozen major science curriculum studies being conducted in the elementary school today. Its strategies of learning appear to be on a solid foundation when compared to the criteria set down by a recent Conference on Science Concepts called by NSTA.[3] Its program is now being tested by fifteen college test centers and 8200 children throughout the United States. Its worth must still be proven, but the future of this coordinated science and mathematics program appears bright.

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[2] F. H. Flavell. *The Development of Psychology of Jean Piaget.* D. Van Nostrand, Inc., Princeton, New Jersey, 1963. p. 85-237.

[3] Paul DeHart Hurd. "Toward a Theory of Science Education Consistent with Modern Science." *Theory Into Action . . . in Science Curriculum Development.* National Science Teachers Association, Washington, D.C. 1964. p. 9.

# *Disadvantaged Children And Their Parents*

**JOSEPH C. PAIGE**
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Howard University
Washington, D. C.

The Howard University Elementary Science Project (ESP) has been designed to fill some educational gaps of children and their parents that have resulted from economic deprivation. The purposes of ESP are (1) to develop a program of compensatory science experiences for disadvantaged children (K-6) and their parents; (2) to determine whether or not the participation in these experiences by disadvantaged children and their parents can help, in a significant way, to overcome social and personal handicaps which usually attend such privation; and (3) to discover what changes in behavior in both children and parents may result from participation in the project.

The Project, supported by a grant from the Cooperative Research Branch, U. S. Office of Education, grew out of the need to provide innovations to conventional efforts in education that schools in deprived areas either could not or have failed to provide for their students. The program attempts to involve children and their parents simultaneously. Children from kindergarten through sixth grade are given simple instructions for participation in science experiences, to be performed jointly with their parents at school or in their homes.

Project investigation has suggested an urgent need for some drastic reforms in the teaching of science in slum area public schools. ESP research also suggests some basic weaknesses in the teaching of some nonscience subjects. Hence, the Project has many implications for school systems which have not found adequate means of dealing with these disadvantaged children.

### Cooperating Centers

Cooperating centers have been established in Washington, D. C., North Carolina, and New York City. (In Washington, D. C., the Katie C. Lewis School and the New Samaritan Baptist Church serve as centers. In North Carolina, four rural groups comprise one center. In New York, The East River Children's Center of Mills College of Education serves as the center.) Discussions are also under way to use the Project materials in some of the programs of the Howard University Community Service Center and the Model School System of the District of Columbia. More than 300 children and their parents have used the materials in cooperating centers of the Project.

### Selection of Participants

When selecting participants for the Project, special consideration is given to persons in the lowest socioeconomic categories. Criteria for family participation in the program includes the following:

1. Residence within the area of a cooperating center;
2. Agreement to attend Saturday sessions by all siblings in grades K-6, and at least one parent or adult member of the household;
3. Free of any physical disability that might impede reasonable participation in program activities;
4. Free of serious behavior problems which the project staff considered undesirable from the point of view of classroom control or teacher effectiveness;
5. Reasonable facility with the English language; and
6. Socioeconomic status of the family within the range generally described as representative of "deprived" or "disadvantaged" circumstances, except in special cases.

### Procedure

The operation is divided into four phases. Phase I covered the period of March 1-September 30, 1964; this phase consisted of the development and testing of some materials with respect to their utility. A Summer Writing Conference comprised Phase II. Phase III (still in process) consists of expanded development and testing of materials produced during the Summer Writing Conference of the 1964-65 school year. Phase IV will deal with evaluation of the 1964-65 trial materials, a writing conference, and Project expansion.

Each Project center works with twenty families. Coordinators and interviewers are assigned to explain the Project to the families in home visits. This prepares families for the science experiences to be conducted at home and group meetings, and to establish liaison between the families and the center group. All ESP personnel are readied for this work by an orientation program which includes the following topics: (1) assumptions and aims of the Project, (2) social problems and resources in the local area, (3) problems of communication, (4) methods for approaching, interviewing, and working with disadvantaged persons, (5) group dynamics, and (6) use of the science materials.

### Volunteer Assistants

Nonprofessionals comprise the corps of volunteer assistants for the Project. The volunteers are, for the most part, undergraduate college students, high school graduates, and some school dropouts. All volunteers are trained by the Project staff. A volunteer worker has a threefold role. He serves as interviewer, tutor, and aide. As interviewer, he has the responsibility of visiting the homes of a specified number of families to establish necessary rapport, and to collect pertinent data. The volunteer also participates in scheduled periodic interviews usually held by a Project staff member on Saturdays following the science participation session.

As tutor, he visits homes and assists children and their parents in performing their home science experiences. His responsibility as an aide is to assist the teacher-coordinator in all aspects of the science participation program.

Individual histories, reports from interviews, observations of classroom teachers, and other reports of the participating families are made available to the volunteer assistants. This background information enables the assistant to evaluate the progress the entire family is making during their participation in the program.

### Home Visits

Home visits by coordinators, interviewers, and volunteer assistants help to effect cooperation among family members in performing the experiences and to prepare them for sharing as families in the programs at the center. Several interfamily projects have been established at the centers.

### Supplementary Meetings

Additional sessions for children and adults are scheduled at various homes. These sessions may center around one of the science experiences, a related area, a new science topic, or any area of interest to the group. These sessions are aimed at raising questions of personal and community health and welfare, suggesting relations between science and other areas, and broadening general experiences. In performing the science experiences at home, participants are encouraged to cope with problems in their own way and to follow-up whatever new problems develop.

### Small Group Organization

The organization of the centers into small groups has several advantages. It facilitates the coordination of Project operations and observations. Participants seem to develop (1) a sense of individual pride through increased general literacy and scientific literacy in particular, (2) a sense of family pride and harmony through successful interactions in a common experience, (3) the power of articulating needs through science experiences, and (4) a new awareness of the world in which they live.

### Design of Experiences

1. *Materials:* Materials for the experiences include science packets, kits, and simple items adapted to the disadvantaged persons. The Project also draws materials from other national science programs, adapting them when necessary to fit into the aims of ESP. To date, the Project has used modifications of material developed by the Elementary Science Study, Educational Services, Inc.; Science Service, Inc.; Science Materials Center, Inc.; and Ward's Natural Science Establishment.

*Under the supervision of Project Director, Joseph Paige, a child and his parent experiment with some of the ESP materials in their home. These materials will be the child's to keep and may open new doors for him and his parent.*

2. *Plan:* The assumption is made that the attention span of our participants is short; discouragement is easy. Hence, the science experiences are designed to be short and simple, yet probing enough to arouse and hold the interest of children and adults. Each experience is designed to allow the participants to make his own discoveries.

3. *Format:* Elementary Science Project kits present wide flexibility with respect to the interests and abilities of family groups. Each kit consists of some simple materials and a work booklet which takes into account the limitations of the participants.

The organizational format of the work booklet provides a minimum set of directions, guiding the children and their parents through the experience by raising questions. Observation and our experience has shown that questions raised by the child- or parent-manipulator and the "trial" and "error" follow-ups, are far more significant than the questions suggested by the materials. The answers to these questions have taken a variety of forms, some have required thought, others have required careful experimentation, and detailed observations.

The design of the science experiences are basically open-ended. Materials have been designed to help the experimenter to develop a logical consistency in his explanation, rather than seeking a correct answer. Understanding of a particular concept or generality is emphasized. "Yes" or "no" answers to questions are discouraged in all Elementary Science Project experiences. Instead, discussions are encouraged whenever questions are raised. In fact, a major provision of the Project plan is that discussion will develop concurrently with the experimentation.

Fifty experience packets have been tested by the Project staff. These materials were the products of the 1964 Summer Writing Conference and cover such diverse topics as: light, color, heat, pressure, friction, nutrition, sensual perception, crystals, metals, magnets, suction cups, and taste. The selection of these topics was somewhat arbitrary, but the staff thought that they would serve to encourage discovery, inference, exploration, observation, and other competencies, attitudes, and skills.

The design of the science experience is to help participants learn (1) how to observe and to keep accurate records of their observations, (2) how to follow directions, (3) how to make accurate measurements, and (4) how to apply some of what they learn to daily living.

One other objective of the Project is the hope that through home and group activities, the subjects might gain experience in (1) meeting unexpected situations, (2) making initial contact with people, (3) arousing interest in problems of mutual concern, and (4) soliciting and utilizing the opinions of others for constructive individual and group action.

## Evaluation

At this time, the real value of the Project is difficult to appraise. Parent participants in the Project, rarely, if ever, attended the meetings of the parent-teacher associations, neighborhood clubs, or community civic groups. The children had occasionally attended after-school programs at school, church, or a movie, but seldom, if ever, with their parents. After they had been helped individually in their own homes and at the Saturday sessions, many of these family groups began to relate to each other, to their neighbors, to the community, and to the school. The success of ESP will have to be measured in the positive behavior changes of the children and their parents, as reflected in improved reading and verbal skills, development of scientific attitudes and reasonable competencies, improved human relations practices, and more specifically, in the willingness to share community leadership and work for the solution of community problems.

**The American Association For the Advancement of Science (AAAS) Elementary Science Project**

# "SCIENCE — A PROCESS APPROACH"

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One hundred and six teachers in twelve centers located throughout the United States have been trying out and evaluating a new science program, and all of its materials, for grades K-3. This experimental program is the outcome of a series of conferences which started in the winter of 1961 and culminated in an 8-week writing conference at Stanford University, Stanford, California, during the summer of 1963. The project is the principal activity of the American Association for the Advancement of Science (AAAS) Commission on Science Education. The Commission is made up of scientists, school administrators, teachers, and science educators; and is under the chairmanship of Paul B. Sears, Yale University, New Haven, Connecticut.

The Commission sponsored two, 8-day conferences during the summer of 1962. One of these conferences met at Cornell University, Ithaca, New York, and the other at the University of Wisconsin, Madison. From these conferences came the theme of the AAAS elementary science program—"A Process Approach." The Commission conferees felt that science is more than just a body of facts. Science, they felt, also includes ways of investigating and ways of explaining. The ways of investigating—The Processes of Science—are stressed in the early grades of the AAAS program.

Each of the exercises in this program was written to develop the child's ability to observe, to measure, to communicate, or to use another of the processes of science. In these early grades, the processes used include: recognizing space/time relations, observing, classifying, using numbers, measuring, communicating, inferring, and predicting. An example of the way in which one process is developed at the kindergarten level is a series of exercises on observation. The various senses are used for observing in these exercises entitled: *Observing Color, Shape, Size, and Texture; Perception of Sound; Perception of Odor; Observing Temperature; Observing Hardness; Observation of Color and Color Changes in Plants;* and a culminating exercise, *Observation Using Several of the Senses.*

Members of the summer writing group at Stanford represented various disciplines and educational levels. About two-thirds of the writers were university people from the fields of astronomy, biology, chemistry, geology, mathematics, physics, psychology, and science education. The rest were elementary school teachers and supervisors.

Every two weeks during the 8-week session, the participants were regrouped into small committees. Each committee spent two weeks writing exercises for a particular process and grade level. To emphasize the process approach, the writers began each exercise with a clear statement of objectives. For example, the exercise entitled *Observations on Rolling Balls* begins with this statement:

> At the end of this exercise, the children should be able to describe the rolling of balls down an inclined plane with particular attention to relative rates of rolling. They should also be able to distinguish between a solid and a hollow ball by watching their relative rates of rolling when someone else rolls them down an inclined plane.

At the end of each exercise, the writers included an Appraisal Activity which the teachers use to determine whether the activities in the exercise have developed the intended abilities in the children.

Evaluation of the materials during this first trial year has been carried on by the staff of AAAS. Each teacher is given a "Check List of Competencies" which she uses with a sample of three children from her class and returns to AAAS headquarters for tabulation and analysis. The three children are selected at random at AAAS headquarters from the teacher's class list and a different group of three children are tested each month.

The following selection from the Check List, for the exercise entitled *Observation 2—Perception of Sound,* will illustrate the nature of the Check Lists. This exercise is taught at the kindergarten level.

> Tell the children they are about to hear a series of sounds. One of the sounds in each series does not belong with the others. Your problem will be to identify the sound which does not belong. You will be told all of these sounds are connected with an automobile, or farm, or some other broad category.
>
> A. The teacher is to tell the child, "Each of these sounds is

supposed to be connected with an automobile. Listen for the sound which is not."

1. auto horn
2. screeching of tires
3. wood being sawed
4. motor accelerating

The sounds are recorded on a tape which the teacher plays for the child. She checks "yes" if the child correctly identifies "wood being sawed" as not belonging in the list and "no" if he does not.

Since the checking is done on a binary scale—yes or no—there is little chance for ambiguity. Either the child has developed the ability or he has not. All of the children in the tryout classes will be checked at the end of the school year with a test instrument designed to determine their abilities to use the processes in new situations. For comparison, this test will also be administered to some classes that have not used the AAAS materials.

Exercises stressing the process approach are novel in elementary science education, particularly in the earliest grades. During the Stanford writing conference it was necessary to determine what kinds of activities were appropriate for children in kindergarten, first, second, or third grade. Much help came from demonstration classes which were held to try out the materials as they were written. The children in one class had just completed kindergarten and the other, first grade. Activities from most of the exercises in *Science—A Process Approach* were taught in these classes—some by a demonstration teacher and others by the writers themselves.

Further evidence for the appropriateness of the activities for the various grade levels is coming from feedback forms which the teachers send to the staff at AAAS headquarters. On these forms, each teacher gives her subjective impressions of how well the children performed, what problems arose, and what suggestions she has for modification. In addition to this, the AAAS staff has observed the teaching in many classrooms.

The results this year have been encouraging. From the Check Lists of Competencies, it is evident that the children have acquired the desired abilities for about 80 percent of the items checked. Both children and teachers seem to be enthusiastic about the materials in spite of the fact that the tryout teachers were not selected because of any particular skill or interest in science. Some scientific help for the teachers is provided by the science consultants at biweekly meetings, but no formal training program has been set up.

During the summer of 1964, another group of writers will use the evaluation data from the tryout program in deciding how the exercises should be modified for the 1964-65 tryout. During the 1964 writing session, materials will be prepared for grades 4 and 5. These also will be tried out along with the revised K-3 exercises during the following academic year.

# New Forces Affecting Science In the Elementary School

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Although the origins of science in the elementary school can be traced back 100 years or more, it is just within the past decade that the teaching of science for children has become a major concern in the school program. On the research front in science education, many agencies are carrying out a wide variety of studies. Elementary school science today is entering a period of great ferment, growth, and change. The last ten years have seen the birth of a worldwide movement to reappraise and remake education in almost every subject and at all levels. During the next ten years we shall be in a period of testing the wealth of ideas arising out of this movement.

The basic cause of this movement is probably the fantastic growth of scientific knowledge and its impact on human life. This "explosion of knowledge" in all the sciences is producing an equally great upheaval in science education. In this article, some of the applications now being made of the new insights about nature and man will be examined for the teaching of elementary school science.

### The Scientists as a Dominant Force in Science Education

The most dramatic accomplishments of the new movement in science education have been the national-level curriculum projects developed for *high school* science courses. These courses have influenced the teaching of elementary school science because of their nationwide scope and support by the scientific community. Some of their features are reported here as patterns that will undoubtedly be applied to a similar remaking of science programs for the elementary school.

The high school projects bear such titles as PSSC (Physical Science Study Committee), BSCS (Biological Sciences Curriculum Study), CHEM Study (Chemical Education Material Study), CBA (Chemical Bond Approach), and others.

Perhaps the most significant point about the new programs is that for the first time in over a generation, a number of research scientists have assumed a major share of the work, along with science teachers. Because the initiative and leadership of the new projects have been mainly in the hands of scientists, almost all of the programs show strong similarities in their aims and methods, and the materials produced. With the support of millions of dollars in federal funds, and operating in nation-wide committees, these projects have now involved hundreds of schools, thousands of teachers, and tens of thousands of students. The materials developed are extremely comprehensive in scope and depth. The biology program produced 40 volumes of textbooks, laboratory manuals, research studies, monographs, teacher guidebooks, tests, films, and other teaching aids. Experimental versions of these materials were tested in the schools, and then rewritten and retested a number of times. These thorough and authoritative programs have profoundly affected the teaching of high school science almost everywhere. Their success has made the scientist one of the dominant forces influencing science teaching today.

### Implications of the High School Science Programs for Elementary Science

Now that the high school projects are launched, the attention of the scientists and scientist-teachers is turning to the elementary school. Up to this point the participation of scientists in reorganizing science courses has been limited to their special fields of expertness in physics, chemistry, and biology. The science specialist views as unmanageable the broad, general approach to the total world of science which characterizes elementary and junior high school. Nevertheless, as they acquire more experience with the problem, we shall no doubt find increasing numbers of scientists deeply involved in elementary school science in the very near future.

The subject-matter specialists encountered many of the problems listed below in designing the new high school programs. Wherever the same problems exist in present courses and methods of teaching elementary school science, similar solutions will quite likely be applied.

### The Knowledge Content of the Science Courses

1. *Inaccurate and obsolete information.* The scientists felt that many of the textbooks used in high school science courses did not reflect the modern approaches of scientific research, nor present the major ideas of each discipline in some unified manner. It should be noted that many of these inadequacies were due to the virtual absence of scientists from the textbook-writing scene for many years. In the new texts, an extremely high standard of accurate and significant information has resulted from the work of many specialists, each writing in his own particular area of competency within a single field of science.

2. *Too much content, shallowly surveyed.* As scientific knowledge grew, extra sections and chapters were added, but little was discarded. The new courses are based upon only a few of the major ideas of each science rather than a mass survey of an entire field. Superficiality is avoided in these new efforts by studying in depth rather than breadth. The CHEM Study group, for example, identified five main areas as the "irreducible minimum of basic fundamentals" that can and should be taught in a first chemistry course.

3. *Conventional science programs needed "purification."* In older courses of study, the amount of attention devoted to "pure" science was out of balance, or confused with its technological applications in medicine, industry, and agriculture. In the new programs, the content is determined by the intellectual goals of scientific inquiry—the aim of discovering how the universe hangs together.

### The Aims of Scientists and the Objectives of Science Teaching

The nature of scientific inquiry itself was not well understood in older texts and patterns of teaching. If science was, according to a dictionary definition, merely "a body of facts and truths systematically arranged and showing the operation of natural laws," then teaching was largely a matter of confirming and memorizing the established facts and "laws of nature." In the modern view:

> The fundamental characteristic that is common to both children and science is that both are actively engaged in interpreting the objects and events of the environment.[1]

Science is presented as an open-ended, intellectual activity in which what is presently "known" or believed is subject to "change without notice." Scientific theories are, therefore, the best current interpretations that can be made, rather than fixed and absolute dogmas. For both students and scientists, the big ideas are presented to serve the following functions:

a. to satisfy our drive for order and to make sense out of things;
b. to give a logical explanation of observations;
c. to unite a wide range of facts and reveal previously unknown or unseen connections;

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[1] Gerald S. Craig. "Children and Science." *Science Education*, 40:167-179. April 1956.

d. to suggest new ideas for further explorations; and
e. to illustrate the power of scientific knowledge in changing our comprehension of ourselves, our world, and our destiny.

### The Processes of Scientific Research

1. *Using the scientific method.* The ways in which new knowledge is gained and tested, and old errors eliminated, were all too often given as a series of somewhat mechanical steps called "*the* scientific method." The new programs try to convey to students that the construction of a theory or conceptual model is a creative act that follows no standard procedure. The testing of this model, however, can follow the regular process called the scientific method.

2. *The role of direct experience in the laboratory.* The activities in many high school laboratories were based on "experiment" manuals proving or confirming well-known principles. Laboratory activities in the new programs require instead investigation, exploration, and genuine problem-solving on a level suitable for all secondary school students.

In one of the newest experimental programs in elementary school science, the Elementary School Science Project of Educational Services, Inc. (ESI), the trend to increased laboratory work has been carried to its ultimate conclusion; laboratory activities have completely replaced the textbook as the main thread of continuity in the course. In effect, the children write their own "textbooks" based on their observations and use texts as supplementary references. This is in sharp contrast to almost all other elementary science programs.

3. *Science equipment and materials.* Truly creative efforts have gone into designing simple and inexpensive equipment for teaching the new courses. Their low cost makes it possible for every student to carry out his own laboratory activities instead of relying heavily on lecture-demonstrations by the teacher.

In the ESI Project, children attempt to discover mathematical relationships by weighing, measuring, graphing, and using similar mathematical tools and concepts in their laboratory experiences.

### A Critique of the Scientist as Curriculum Maker

The new programs represent major breakthroughs in the development of courses of study, materials, and teaching methods. Each group has taken a completely fresh look at what should be taught and how it should be taught, but *primarily from the scientist's point of view.* The rise of the subject-matter specialist to a prime position of influence once again recalls some long-standing problems of educational philosophy. Does the scientist's outlook sufficiently acknowledge the broader aims of education? To what extent can programs based mainly on learning the intellectual structure of various fields of knowledge promote children's growth and development in such important dimensions as the social, emotional, physical, esthetic, moral, and economic. What should be the attitude of the teacher, and other "specialists in children," toward the impressive work of the specialists in knowledge?

At the same time the new movement in science education was getting underway, Gerald Craig, the "father" of elementary science, wrote:

> Children are greater than science. Science has importance in elementary education only as it serves boys and girls and through them the democracies of which they are a part. It is so easy for specialists to become enamored with their own special fields and to lose sight of the learner in teaching the subjects. The elementary school . . . is no place for the specialist to "strut" his specialization. The question . . . can never be what is "best" for science, rather . . . what is "best" for children.[2]

Such criticism may seem unjustified to the authors of the new programs, when they have, in fact, tried to aim their courses at the "typical" high school student for the express purpose of general education for all youth. Large-scale testing has confirmed the successful achievement of two out of the three prime objectives of the new programs: (1) to impart the essential structure of each science, and (2) to convey the nature of the scientist's methods and outlook. The supremely important third objective remains to be adequately implemented and evaluated. This is, to develop human beings who will use their knowledge of science to make intelligent decisions about the complex problems of modern times, be they personal, social, national, or global. Although this objective is found in some form in the prefaces to all the studies, operational steps and materials are not provided for its realization. It seems to have been assumed that desirable attitudes and behavior patterns will result automatically by massive transfer from learning about the pure science, a position which ignores much educational history on this point. Even direct teaching about problems in which science impinges on life, only rarely produces changed behavior and attitudes. "Living with atoms is no substitute for dealing with atoms and men!"

All of which merely illustrates the need for a more balanced approach to the never-ending task of building the ideal curriculum, and not jumping on the bandwagon of the new movement in science education. The curriculum projects, as admirable as they may be, are, in fact, only partial contributions to the solution of the problem. They are intended to be highly creative and reliable resource material for teachers, school systems, publishers, equipment manufacturers, and all others who have a share in educating the nation's youth. They are not nationalized curricula, standardized syllabi, or prescribed courses of study. The overall planning and implementation of educational programs still requires attention to many other considerations, even after the scholars of the formal disciplines have done their work.

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[2] Gerald S. Craig, *op. cit.*, p. 5.

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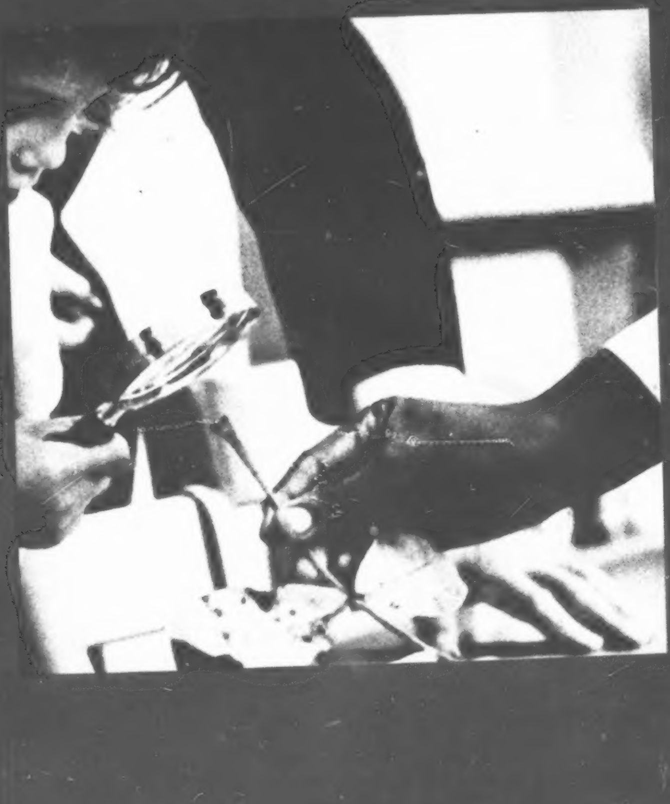

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